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For the First Time Ever — Wide-Field Schmidt-Cassegrain Telescopes that Yield a 60% Reduction in Photo Exposure Times!

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1 Fast f/6.3 Schmidt-Cassegrain Optics — *Optics that yield photographic and visual performance impossible to achieve with the f/10 optics that are standard on all other SC telescopes. Eyepiece for eyepiece, obtain:*

☐ A field of view that is **59%** wider than with f/10 Schmidt-Cassegrains. Use the Meade Super Wide Angle 40mm eyepiece on the 8″ LX6 to obtain a true field over *2 degrees* in diameter!

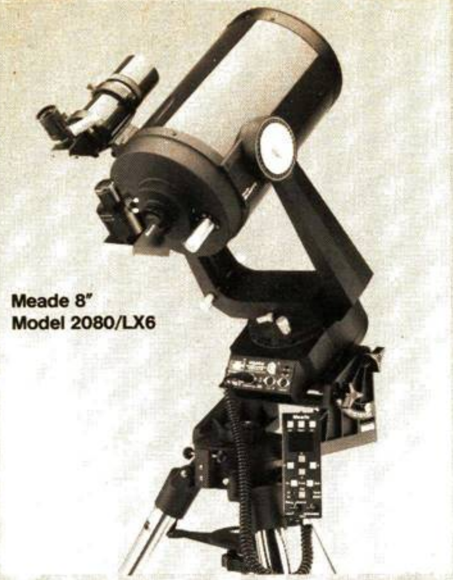
☐ Images both visually and photographically that are **2 ½ times** brighter than with an f/10 system.

☐ A **60%** reduction in astrophoto exposure times: 30 minute exposures become 12 minute exposures. Used with modern fast films, a **5-minute** color exposure of the Orion Nebula (M42) taken with the 10″ Model 2120/LX6 *yields virtually all of the nebular detail that is theoretically possible to obtain with a 10″ telescope!* With the optional Meade **Telecompressor Lens**, for an effective focal ratio of f/3.15, this exposure time is reduced still further to about **3 minutes** — an unheard of exposure time for a photo-visual telescope of 10″ aperture, an exposure time that means *anyone* with an absolute minimum of experience can take magnificent deep-space astrophotos!

2 Ultra High Contrast Baffling — In addition to their superlative wide-field deep-space performance, Meade 8″ and 10″ LX6 models, because of their computer-optimized internal light baffles, yield uncompromised, high-contrast lunar and planetary images. Add the Meade 3-element **#140 2X Telenegative Barlow Lens** to obtain high-power lunar and planetary images at f/12.6.

3 Built-In Digital Readout Capability — One of the most important optional features ever made available on a Schmidt-Cassegrain: now you can find faint objects in seconds, not minutes. The LX6 Digital Readouts, located on the hand controller display, permit continuous monitoring of: *(a) telescope position in RA and Dec; (b) Local Time; (c) Sidereal Time; (d) a Digital Timer for photo exposures; and (e) Frequency readout of the pulse motor's input current* — a feature that enables extremely precise digital settings of the telescope's drive rate, readable to within ±.01 Hz. The observer simply depresses the "Mode" button on the hand controller to read out the listed data sequentially.

The Digital Readout package can be internally added easily and rapidly to the hand controller of your LX6, either at the time of purchase or at any future date, and is available at only modest additional cost.


Meade 8″
Model 2080/LX6

4 New Multi-Function Electronic Command Center — The ECC hand controller, included as standard equipment, puts virtually every telescope function at your fingertips:

☐ *2X Drive Correction Speed* for precise electronic corrections during astrophotography.

☐ *8X Scanning Speed* for rapid electronic centering of the image in the field, or for roving about a specific sky region at 8 times the sidereal speed. Add the optional Declination motor for full dual-axis capability at 2X or 8X speeds.

☐ *Optional Digital Readouts*, described above.

☐ *Plus 6 other functions* that make Meade LX6's the only state-of-the-art Schmidt-Cassegrains available.

5 Quartz Microprocessor-Controlled Electronic and Drive Systems — The heart of every LX6 electronic system is a dedicated microprocessor that continuously controls, with quartz precision, all important electronic operations of the telescope, from the drive-rate frequency input to the main RA pulse motor, to the Electronic Command Center's multi-function digital readouts.

Augmented by the microprocessor, the RA pulse motor and LX worm gear system achieve true sidereal-rate tracking within ±.005% of the sidereal frequency, and with greater reliability than ever before. Switch to the "Manual" mode for variable Solar, Lunar, or Planetary tracking rates.

6 Advanced-Design Power Panel — Virtually every modern electronic accessory you might wish to add to your LX6 can be plugged-in directly to the telescope's power panel — accessories including the Meade **CAT Computer Aided Telescope** system *(see our other ad in this issue)*, with its library of more than 8000 astronomical objects; **Digital Readouts**, readable on the LX6 hand controller *(see above)*; **#1200A Electric Focuser**, for ultraprecise microfocusing; **12mm Illuminated Reticle Eyepiece**, for guiding during astrophotography; and the **Declination Motor**, for 2X/8X dual-axis operation.

In addition, the LX6 power panel includes an **Ammeter**, which continuously displays electric current usage, to gauge battery life during power cell operation; a **North-South Switch**, permitting your LX6 to be used anywhere in the world — simply flip the N-S switch to reverse drive direction for use in the Southern hemisphere; and **12-volts DC Power Inlet**. Each LX6 includes power cords for *3 types* of field operation: Directly from auto cigarette lighter plugs; directly from 115v. AC home outlets; and from the Battery Pack, included, using AA-size batteries supplied by the user.

7 Plus all of the features you expect on a top-of-the-line Meade Schmidt-Cassegrain — *Standard* features that include a **Super Plössl 26mm eyepiece** for exquisite definition and resolution across the entire visual field; 1/10-wave flat, multi-coated **2″ Diagonal Mirror** with eyepiece holders for both 1¼″ and 2″ eyepieces; **9 x 60mm Polar Illuminated Viewfinder**, the largest finder available on a commercial SCT; **Multi-Coated Optics Group**, with multi coatings on all lens and mirror surfaces for maximum light transmission and image brightness; **Equatorial Wedge**, with magnetic compass, latitude scale, bubble level, and micrometric azimuth control; and **Variable-Height Field Tripod**, the most stable in the industry.

Priced only slightly higher than conventional f/10 Schmidt-Cassegrains, Meade 8″ and 10″ LX6 models achieve photographic and visual performance levels unobtainable with any competing telescopes.

Call or visit your Meade dealer now for further details and prompt delivery of the Meade 8″ Model 2080/LX6 or 10″ Model 2120/LX6 — from the World's leading manufacturer of Schmidt-Cassegrain telescopes.

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ON THE COVER: The Orion Nebula glows with the light of young stars like an enormous celestial flower. On page 82 Jack Newton tells how he makes stunning astrophotos like this one.

ORION SLIPS westward while a lone stargazer explores another region of the sky. New fast films (see page 100) can capture scenes like this in a few seconds. Photo by Jerry Schad on 3M 1000 film.

ASTRONOMY®

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Mercury's huge iron core and violent origin have generated new interest in a planet once thought dull. By Clark R. Chapman.

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SEEING IS BELIEVING

Two hundred and fifty years ago the infant William Herschel first opened eyes destined to see the universe in new ways. A late-blooming amateur astronomer, Herschel stayed away from the complex and technical positional astronomy of the day, seeking instead to deduce the physical nature of the stars. With a 6-inch telescope he set out to survey the heavens in search of double stars but instead turned up a new planet — Uranus.

Why had Herschel been looking for double stars? He wanted to determine the distances to stars, and he reasoned he would see parallax as the Earth's motion shifted the foreground star relative to the background star. By watching them systematically, Herschel discovered instead that doubles are often pairs of stars that orbit each other and, because the component stars are unequal in brightness, that stars differ in brightness.

Herschel's continuing sweeps of the heavens with larger and larger telescopes turned up thousands of faint nebulae — he could only guess what they might be — and his systematic counts of the number of stars yielded the first "picture" of our Galaxy as a thin disk of stars floating in space.

We remember William Herschel today because he saw the heavens in new ways — not because he found answers. Although his tools and techniques were too crude to answer the questions he asked, we admire his energy and enthusiasm in seeking answers to big questions about the universe. Our story on Herschel begins on page 40.

Nowadays amateur astronomers use photography to see deeper into the cosmos. Photography substitutes sensitive crystals of silver bromide for the rhodopsin in our eyes to register light. The image reveals in minutes or hours the structure that we could never see directly. Whether we apply the techniques it has taken Jack Newton decades to perfect or the hottest new films from Kodak and Konica, we're exploring the cosmos with our pictures.

But it still takes the eye to see the light and dark patterns recorded on film and the brain to *interpret* them as remote clusters of stars, bright hydrogen clouds in the depths of our Galaxy, or stars whirling in the arms of spiral galaxies. With the same appreciative eye that William Herschel would have cast on them, we invite *you* to survey the celestial wonders amateurs have captured on film.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

Hidden by Lunar Mountains

I would like to make a correction to "Charting Mountains on the Moon" by Robert Reeves, Rick Frankenberger, and me (August 1988). The caption for the computer graph of our observations on page 73 and the explanation of the graph on page 74 state that each horizontal line represents the period during which El Nath was visible from a given observer's vantage point.

The horizontal lines are, in fact, the regions where the star was *hidden* by the lunar mountains. On that graph the lines connect the points of disappearance with those of reappearance. — *Ron Dawes, San Antonio, Texas*

'Sky Scanners' with a Twist

I used the general idea of "Build a Binocular 'Sky Scanner'" by Bryan P. Shumaker (February 1988) but made a few changes for a more solid scanner.

The major changes were in the mounting for the binoculars. I built an aluminum frame, which attaches to the top board with a thumbscrew going into a T-nut. Elastic is attached to the frame and the binoculars for solid, easy eye-width adjustment. The mirror is held in place with faucet washers instead of silicone adhesive, in case I need to remove it.

The unit is quite strong and works even better than I imagined it would. The scan runs from the horizon to about 120° and the viewing is truly magnificent through my 10x50 binoculars. What a pleasure it is to wide-scan the sky without having to move. — *Walt Niblick, Jacksonville, Florida*

I couldn't wait to take advantage of viewing the night sky without ending up with a stiff neck and shoulders after I read "Build a Binocular 'Sky Scanner'".

I added the base of an old lazy Susan with three extended legs made from shelf brackets with rubber pads at the ends. With this feature I can rotate the Sky Scanner without having to lift the unit. I also made a felt-covered protector for the mirror. — *John F. Luman, Jr., Enfield, Connecticut*

A Stolen Telescope

We are looking for information to help us locate a stolen telescope. Weil Observatory, operated by the Albany (New York) Area Amateur Astronomers, was broken into on August 17, and virtually everything was stolen, including a 12-inch f/16 Tinsley Cassegrain telescope on an observatory-style pier.

Except for the focuser, internal light baffles, counterweight, and finder, the telescope has all its original parts. It is

Tele Views

TOPICS OF INTEREST FOR TELESCOPE ENTHUSIASTS.

#1

FIELD OF VIEW – WHAT DOES IT REALLY MEAN?

One of the least understood specifications of telescopes and eyepieces is "field of view." Terms like "true field," "real field," "angular field" and "apparent field" are often confused. Let's try to clarify them.

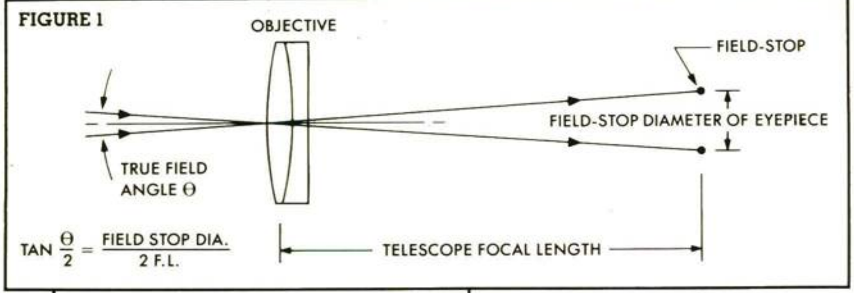
TRUE FIELD:

True field is determined by the telescope focal length and the diameter of the field-stop in the eyepiece (as shown in figure 1).

"True field," "real field," and "angular field" mean the same thing: the angle of view of the outside world, as limited by the field-stop diameter of the eyepiece. For a given focal length telescope, it's easy to see that a *larger* eyepiece field-stop gives a larger true field angle. Or, for a given field-stop diameter, a shorter focal length telescope similarly results in a larger true field angle.

You can measure the *field-stop* diameter of the eyepiece with calipers (eyepieces with field-stops between lens elements, such as Nagler types, cannot be evaluated without a detailed knowledge of the optical design). The field-stop size is obviously limited by the inside diameter of the eyepiece barrel (2 inch barrels allow 3x more potential field area than 1¼ inch barrels). The "star-drift" method described in books and articles can also be used to find the "true field" of the telescope.

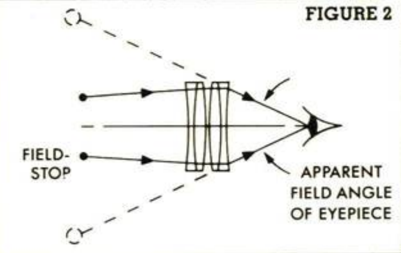
FIGURE 1


OBJECTIVE
FIELD-STOP
FIELD-STOP DIAMETER OF EYEPIECE
TRUE FIELD ANGLE θ
TAN θ/2 = FIELD STOP DIA. / 2 F.L.
TELESCOPE FOCAL LENGTH

APPARENT FIELD:

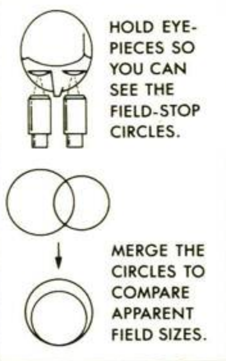
Apparent field is the projected angle of the field-stop, as seen through the eyepiece. It is a characteristic of the eyepiece *alone* (see figure 2).

FIGURE 2



No telescope is needed to compare the "apparent fields" of two eyepieces. Holding eyepieces up to each eye so that the field-stop images appear to merge (as in using binoculars) is instructive in comparing "apparent fields" (as shown in figure 3). Just note which field-stop circle appears larger.

FIGURE 3


HOLD EYEPIECES SO YOU CAN SEE THE FIELD-STOP CIRCLES.
MERGE THE CIRCLES TO COMPARE APPARENT FIELD SIZES.

"Apparent field = true field x magnification" is a formula that is *not* accurate for calculating the apparent field of wide angle eyepieces, because their magnifying power is generally non-linear across the field. This is why the "star-drift" method to measure true field cannot be properly used to determine apparent field.

In summary: For comparing true fields, simply measure the eyepiece field-stop diameter. For comparing apparent fields, just view through the eyepieces to see which field-stop circle appears larger.

Eyepieces that utilize the entire inside diameter of their barrels will deliver the largest true fields possible. Examples are the Tele Vue 55mm, 40mm and 32mm Plössls.

Apparent field differences of a degree or two aren't very significant, but Tele Vue owners who make the comparisons described will find in most instances that their eyepieces have *larger* apparent fields than competitive models. When that larger apparent field also delivers better edge field correction of astigmatism and lateral color, then you have something even more significant; *performance "even better than you imagined."*

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painted yellow. The telescope was completely restored by the club and represents a great deal of work.

If you hear of such an instrument or desire further descriptive details, please call me or my wife Susan at (518) 374-8460. — *Alan French, President of the Albany Area Amateur Astronomers, Scotia, New York*

Photos Helpful for Tough Objects

Kudos for Mace Hooley's "Conquering the Cepheus Nebula" (June 1988). It is very refreshing to see photos of tough objects that visual observers can use as finder charts or to confirm their own descriptions and sketches.

Mr. Hooley's photo of IC 59 and IC 63 demonstrates a wonderful feature: IC 59's blue color indicates the object is a reflection nebula and the redness of IC 63 means that the object is an emission nebula and, therefore, filters can be used to enhance them. — *Alister Ling, Edmonton, Alberta*

The Dream Is Still Alive

I enjoyed Robert Burnham's review of *The OMNI Space Almanac* (July 1988), but I was saddened that Mr. Burnham no longer finds that the "dream is alive."

What has shrunk the pie is *not* the space shuttle but the funding base. What has also shrunk is the support that Congress and the American people give to the space program.

The public finds the development of better products from space, ways to conduct business operations more efficiently, and ways to improve the quality of their lives exciting. Show Americans a program with these ideas as its base and there will be support for future space science programs. If one program succeeds, interest will be generated for others.

I am sorry that the pain of the *Challenger* tragedy has blinded people to the real problems facing the American space program: not the postponement of missions but the possibility that America may never develop the space infrastructure it so desperately needs. I hope the American public will fund a space station that will advance man's technology. And from that will flow the funds and technology for more advanced missions. That's the dream and it's alive. — *Robert G. Oler, San Antonio, Texas*

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy. Send your letters to: ASTRONOMY Letters, 1027 North 7th Street, Milwaukee, WI 53233. Letters may be edited for length and clarity. □

Viewpoint

AMATEURS AS PROFESSIONALS

by Jacqueline Mitton
Editor of the Journal of the British Astronomical Association, *the national society of amateur astronomers in the United Kingdom, and holder of a doctoral degree in astronomy from Cambridge University*

For someone like me, a professional astronomer and an active amateur observer, it often seems that these two realms of astronomy are worlds apart. But the separation between the professional and the amateur is really an unnatural — and unproductive — division that is now, fortunately, beginning to fade.

Echoing the concerns of several recent meetings that have addressed the issue of professional/amateur cooperation, the International Astronomical Union at its General Assembly last August in Baltimore, Maryland, passed a resolution that recognizes "the long-standing tradition of excellent and practical collaboration which has existed between amateur and professional astronomers" and calls for more communication between the two camps to promote cooperative projects.

The resolution acknowledges just how closely linked professionals and amateurs really are. Many professional astronomers, after all, started out as amateurs. Many other amateurs have passed through the stage of viewing the universe for fun to the point where they want the satisfaction of knowing their observations are scientifically useful. They really want to advance our understanding of the universe, if only a little.

Astronomy remains one of the few areas of science where amateurs can and do make worthwhile scientific contributions. The reason for this may lie in the fact that the basic equipment, when compared with that needed in other branches of science, is easy to obtain, cheap, and made to be used at home.

Historically many astronomers who would be classified as amateurs have been responsible for major discoveries. Perhaps the most notable is William Herschel, who was a professional musician when he discovered Uranus in 1781. It is clear that the transition from amateur to professional was not easy for him. The established scientists of his day did not readily accept as one of their number someone entirely self-taught.

Perhaps the quality that earned Herschel a place among astronomy's greats was his enduring spirit of perseverance in building telescopes and using them on every possible occasion. It is these same attributes — observing skill and commitment to the task — that are exemplified by amateurs today who make contributions to science.

It's important to remember that the word "amateur," when applied to a dedicated observer, is not synonymous with "unprofessional." (Maybe amateur astronomers should be rechristened "voluntary" astronomers to avoid this stigma.) Many amateurs are scientists and engineers and pursue their observations with decidedly professional rigor.

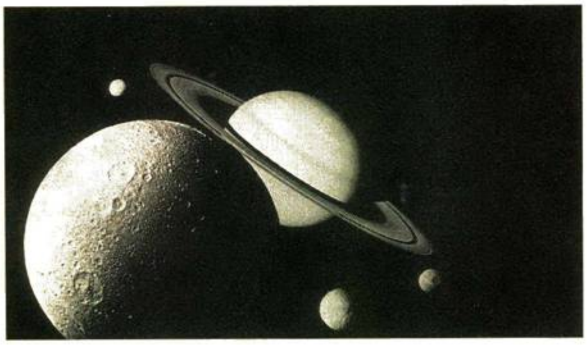
The dedication and enthusiasm of amateurs, coupled with the fact that they have their own telescopes available every clear night, puts them in a special position for many kinds of systematic searching, monitoring, and surveying work. The discovery of a nova, supernova, or comet enhances significantly the value of subsequent observations, while long-term observations of a variable star or Jupiter, for example, may be essential for testing a theory that attempts to explain why particular changes are observed.

The division between professionals and amateurs is unnatural and unproductive.

Although an individual observer may have only limited observing time, a number of amateur organizations around the world have accumulated extensive and valuable archives of data by pooling the observations made by members. Recently amateurs have been able to collect more and more sophisticated data as advanced technologies have become available. Amateurs are using electronic imaging, photoelectric photometry, and computer control that not long ago were the preserves of professionals.

What is needed now are ways to link amateur observers with researchers who could use the help and direct the endeavors of amateurs. More publicity should also be given to the existing collections of amateur data already available to scientists. If enough people can build on the goodwill that already exists between professionals and amateurs, the IAU's resolution might herald a new era of cooperation that can only benefit the whole of astronomy. □

Does exploring other worlds make your heart beat faster?



Help launch a new era in planetary exploration... and enjoy the many benefits of membership in The Planetary Society.

This is an important time for space exploration enthusiasts like you. At no other time in history has the exploration of other worlds held more promise. Through your membership in The Planetary Society, *you* can help fulfill this promise...*you* can have an impact on the exploration of other worlds and the search for extraterrestrial intelligence.

In the last two decades, for the first time in history, we have studied our neighboring worlds close up and in detail—the enigmatic pyramids of Mars, the organic clouds of Titan, the 10,000 Saturnian rings. Right now, the U.S., the U.S.S.R., the European Space Agency and Japan are planning historic space missions. These epic ventures will be remembered by our descendants thousands of years from now when most other achievements of our time will be forgotten.

See the universe in a new light

The Planetary Society, as the world's largest, most influential space interest group, will have an impact on such programs. And you, as a Planetary Society member, will be a part of our efforts. As a member, you not only take a front-row seat in the ultimate adventure in space. Your membership will actually help move ahead international programs to explore the cosmos...will actually help finance the radio search for extraterrestrial intelligence.

Headed by some of the world's most distinguished scientists, The Planetary Society provides more than 100,000 members with knowledge and inspiration that sparks their imaginations and keeps them on the cutting edge of space exploration.

U.S. Planetary missions scuttled. New hopes for new missions.

Since 1978, the U.S. has not launched a single mission to the planets—after dozens of historic missions in the preceding two decades. Today, The Planetary Society is spearheading efforts to renew U.S. commitment to missions awaiting launch: *Galileo, Magellan, Ulysses* and *Mars Observer.* And we are disseminating information to the American people on the ambitious Soviet *Phobos* mission and on future Soviet Mars exploration. We are also leading the drive for a multinational piloted mission to Mars and new expeditions to other planets. We invite you to join us.

Many membership benefits.

There's no other organization like The Planetary Society. When you join, in addition to receiving our colorful magazine *The Planetary Report* six times a year, you'll get special discounts on books, videotapes, posters, prints and other materials. You'll also be invited to special Society events and activities, such as Planetfest '89.

6¢ a day is all it takes!

To become the next member of The Planetary Society, just fill out the Membership Form below and return it right away. Send no money now. We'll bill you for your low membership dues of just $20* a year. That's about 6¢ a day to take part in this unique adventure.

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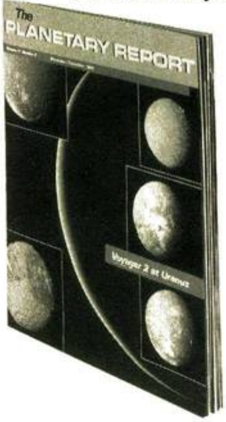

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Co-founders of The Planetary Society: Bruce Murray, Professor of Planetary Sciences, California Institute of Technology (seated left); Carl Sagan, Director, Laboratory for Planetary Studies, Cornell University (seated right); Louis Friedman, Executive Director (standing).

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Send my membership card, start *The Planetary Report* coming to me and bill me just $20* for my first year's dues. Be sure to send me invitations to the Society's special events and activities.

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SUNLIKE STAR HAS PLANETS?

A team of astronomers recently observed small changes in a Sunlike star's radial velocity — changes that indicate at least one large planet is orbiting the star.

Astronomers David Latham, Robert Stefanik, Richard McCrosky, and Robert Davis of the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, and Tsevi Mazeh of the University of Tel Aviv in Israel were observing HD 114762 closely because they intended to use it as a "standard star" of constant velocity for calibrating the velocities of other stars.

Over the past seven years the researchers took high-resolution spectra of HD 114762 and looked for minute shifts in the wavelengths of spectral lines caused by Doppler effects. Instead of showing a constant radial velocity (motion directly toward or away from us), the star's velocity varied periodically by 533 meters a second every 84.2 days — a result best explained by the star and a large unseen planet orbiting a common center of mass.

Because the astronomers cannot tell how much the star system's orbital plane is inclined to the line of sight, they can derive no exact figure for the size of the planet. However, working from theoretical models of solar systems, they think it likely the planet has about ten times the mass of Jupiter. (It could also be a brown dwarf, a small, subluminous object that falls between a planet and a star in mass.) Unfortunately, the planet is too hidden in the glare from the star to be seen directly.

HD 114762 is a magnitude 7.3 star in Coma Berenices about 80 light-years away (α, δ = 13h12m20s, 17°31′00″; 2000.0). It is plotted on chart 150 of *Uranometria 2000.0*, where it lies half a degree east of α Comae and 35′ south-southwest of globular cluster M53. The star's spectral class is F9 V, which makes the star only a little hotter than the Sun. Its companion most likely orbits about as far from the star as Mercury does from the Sun and is probably extremely hot.

THE MOST DISTANT GALAXY — so far — lies at a distance of nearly 12 billion light-years. This photo was taken through the 4-meter Mayall telescope at Kitt Peak National Observatory.

A NEW MOST-DISTANT GALAXY SIGHTED

Yet another claim has been made for observing the most distant galaxy in the universe. The discovery, made by an international team of astronomers, was announced at the International Astronomical Union's General Assembly in Baltimore last August. The galaxy, referred to by its radio designation, 4C 41.17, lies more than 90 percent of the distance out to the edge of the visible universe. The light from this distant galaxy was emitted when the universe was only a few billion years old.

The discovery was made by Ken Chambers, a graduate student at Johns Hopkins University; George Miley, professor of astronomy at Leiden University in the Netherlands; and Wil van Breugel, an astronomer at the University of California, Berkeley. The team pinpointed the galaxy using an all-sky search strategy they developed for locating extremely distant radio galaxies.

After identifying the galaxy as the source of radio emission, the researchers took a spectrum of the galaxy and determined a redshift of 3.8, which corresponds to a distance of nearly 12 billion light-years. This galaxy just beats out 0902+34, a 3.4-redshift galaxy detected in November 1987 by University of Hawaii astronomer Simon Lilly (see "Old Galaxy, Young Universe," AstroNews, September 1988).

Chambers, Miley, and van Breugel also found that 4C 41.17, as well as other distant radio galaxies they have been studying, are very different from nearby galaxies. Unlike normal galaxies, the light in these distant radio galaxies appears to be "stretched out" along the direction of their radio emission. One likely explanation is that twin jets of hot gas are spewing out from the poles of a massive black

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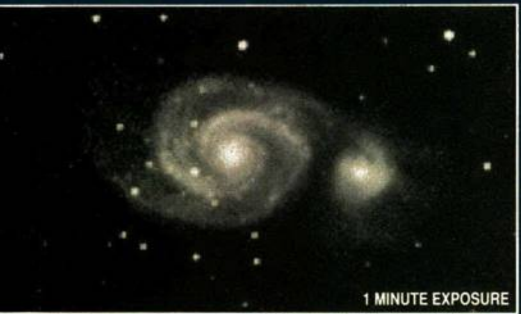
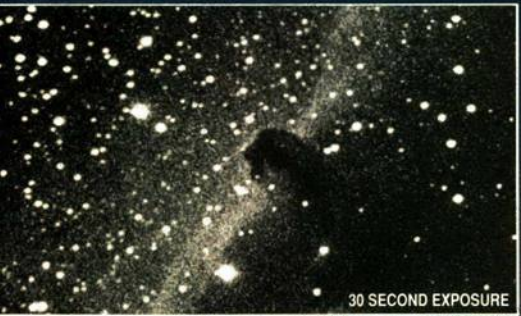


CCD Image M51 f/5 6" Newtonian



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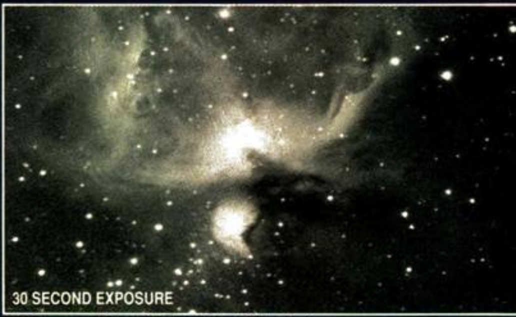
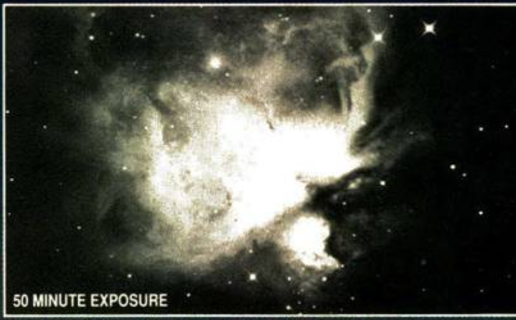


CCD Image Orion Nebula f/5 6" Newtonian



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hole in the galaxy's core, compressing gas and dust along the paths of the jets and triggering star formation. Although this effect is not fully understood, it indicates a close relationship between the starlight presumed to be producing the optical radiation and the powerful radio emission caused by radiation from the jets.

The discovery of differences between objects like 4C 41.17 and nearby galaxies strains explanations of the evolution of the universe that are founded on *similarities* between distant radio galaxies and nearby galaxies. Nonetheless, these far-flung star systems provide an important clue about when galaxies formed. The implication that these galaxies formed only a few billion years after the Big Bang is a notion that runs counter to many theories about the origin of the universe.

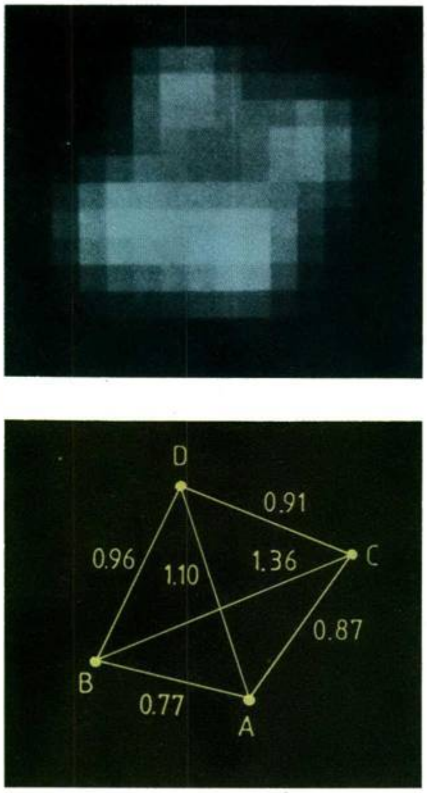
'MULTIPLE QUASAR' PRODUCED BY GRAVITATIONAL LENS

The image of a multiple quasar discovered by astronomers in March 1988 is the result of a gravitational lens. The quasar, H 1413+117, appears as a close group of four images thought to be a lensing effect caused by a galaxy lying between the quasar and Earth. There are several examples of gravitational lensing known, but this is the first time astronomers have observed the multiple image of a quasar. (See "Einstein's Gravity Ring" by Gerrit L. Verschuur on page 52.)

A team of eight European astronomers led by P. Magain of the European Southern Observatory (ESO) photographed H 1413+117 at ESO's La Silla, Chile, observatory. Using a high-resolution CCD camera attached to ESO's 88-inch telescope, the astronomers recorded images of the quasar that showed four lobes separated by less than 1 arcsecond arranged in a cloverleaf pattern.

Magain and his colleagues also used the ESO Faint Object Spectrograph and Camera to record spectra of the two brightest lobes. The spectra were identical, which confirmed that the images were of the same object. Several lines visible in the spectra are caused by the gravitational lens.

Although research on this object has just begun, astronomers are excited about the possibilities H 1413+117 offers. For example, as the quasar varies in light output, the light will pass through different parts of the cloverleaf. Because the different parts of the cloverleaf bend light slightly differently, measuring the time delays of these flashes in different parts of the cloverleaf should enable astronomers to calculate the precise distance of the quasar. This will provide a valuable double check on the value of using redshifts as distance indicators.



THE MULTIPLE QUASAR (top) is an optical illusion produced by an intervening gravitational lens. The quasar's components (A, B, C, D) are separated into a trapezium about one arcsecond on a side.

Studies of the quasar's distance and spectra could confirm what Magain's team now suspects: that the most powerful quasars appear more luminous than they really are because their light is amplified by gravitational lenses.

WORLD ASTRONOMERS CONVENE IN BALTIMORE

Two thousand astronomers from all around the world assembled for a ten-day-long General Assembly of the International Astronomical Union in Baltimore from August 2 to 11. Held every three years, IAU General Assemblies afford astronomers opportunities to meet and work with colleagues from other countries, discuss science policy, and establish means of international cooperation.

The bulk of the work at an IAU General Assembly is carried out in commission meetings — small groups of astronomers interested in a single topic such as binary stars or active galaxies. At present there are forty IAU commissions. Joint commission meetings and joint discussion sessions give rise to cooperative programs with results shared among astronomers working in other disciplines and between observers in widely separated parts of the world.

The General Assembly adopted a resolution proposed by its executive committee on amateur astronomy. "Recognizing the long-standing . . . collaboration which has existed between amateur astronomers and professional astronomers," the resolution reads, and "noting that additional communication for common projects is needed today," the countries of the IAU unanimously voted to establish a working group to foster this cooperation and to inform the amateur and professional communities.

In another resolution the IAU noted "with grave concern" that light pollution, radio interference, and space debris pose major threats to astronomy. It strongly urges all astronomers to "request civil authorities and others in their countries to implement solutions to preserve the quality of observing conditions" and it also "requests the Scientific Committee on Problems of the Environment to study these threats and advise the IAU of its findings."

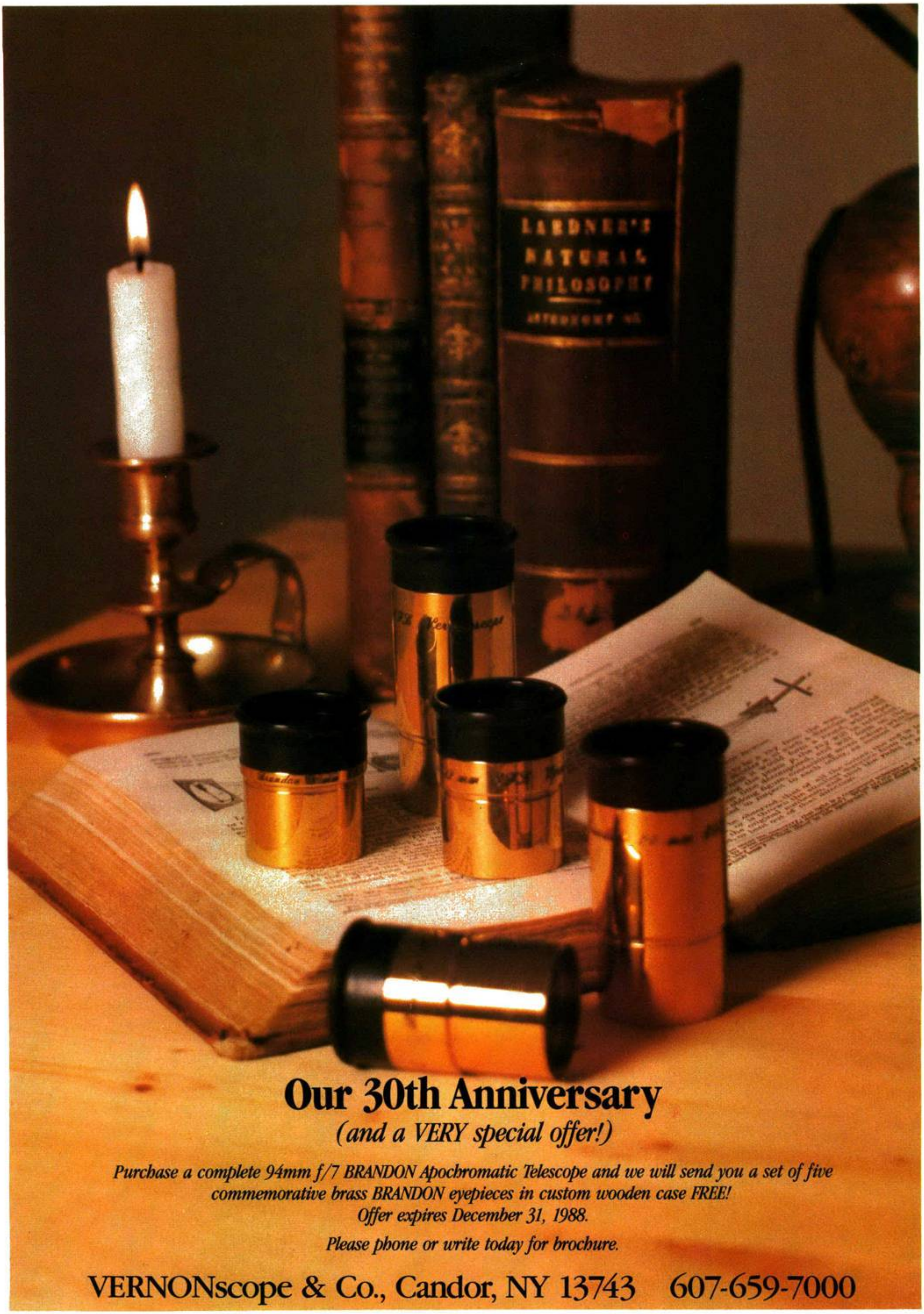
Other resolutions endorsed the International Space Year in 1992, recommended international cooperation to protect the hydroxyl (OH) bands at 1612 megahertz from interference by mobile communications transmitters and satellite navigation systems, and endorsed a new list of internationally recognized radio bands of importance to astronomers.

The countries of Algeria, Iceland, Malasia, Morrocco, Peru, and Saudi Arabia applied for membership in the IAU and their applications were accepted. The IAU meets again in July 1991 in Buenos Aires, Argentina.

COMPLETE RINGS OF LIGHT ENCIRCLE SUPERNOVA 1987A

Last July astronomers successfully photographed two rings of light around supernova 1987A. The rings of light, remnants of the February 1987 explosion of the supernova, had been shown in a photograph made in early 1988. But a photograph made by David Malin of the Anglo-Australian Observatory in July 1988 is the first to show the rings as complete circles.

Malin used the 3.9-meter Anglo-Australian Telescope for an exposure on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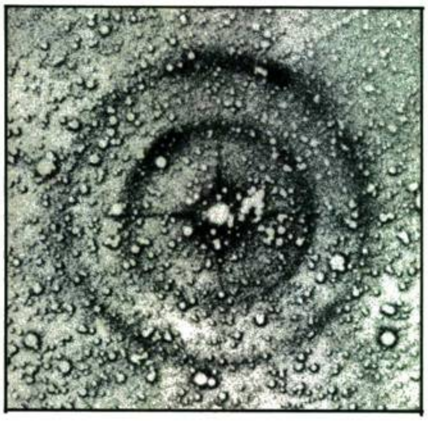
July 15. When he computer-processed the image, subtracting stars and nebulosity using an old photographic plate of the same region of sky, Malin got the photo showing perfectly circular rings.

The rings are expanding shells of gas, presumably from the supernova, that contain a great deal of dust. The inner ring is about 470 light-years from the supernova, and the outer ring — which is not precisely concentric with the supernova — lies 1,200 to 1,350 light-years from the supernova. The orientation of the outer shell suggests it may be centered on the 30 Doradus Nebula, a region of star formation where many supernovae must have occurred in the past. Astronomers will investigate this fact further to see if it is significant.



RINGS OF GAS AND DUST encircle supernova 1987A in this specially processed image made with the 3.9-meter Anglo-Australian Telescope in July 1988.

NEW URANIAN SATELLITE NAMES ADOPTED

In August the General Assembly of the International Astronomical Union formally adopted new designations for the ten Uranian moons discovered by *Voyager 2* in January 1986. All solar system bodies are officially named by the IAU.

Nine of the new moons are named after Shakespearean characters and one is named after the heroine of *The Rape of the Lock* by Alexander Pope. The new names are Puck (1985 U1), Portia (1986 U1), Juliet (1986 U2), Cressida (1986 U3), Rosalind (1986 U4), Belinda (1986 U5), Desdemona (1986 U6), Cordelia (1986 U7), Ophelia (1986 U8), and Bianca (1986 U9).

These satellites are closer to Uranus than Miranda, which orbits the planet at a distance of 130,000 kilometers. Cordelia and Ophelia are the shepherd moons that orbit on either side of Uranus' epsilon ring.

Helene was also officially adopted as the name for the Saturnian moon, 1980 S6, which had previously been called Dione B.

NEW HUBBLE CONSTANT REDUCES AGE OF THE UNIVERSE

The gravitational pull of dense clouds of galaxies in the local universe has led astronomers to miscalculate the age and size of the universe, according to research by astronomer Brent Tully of the University of Hawaii. Tully, who published his results in *Nature* (July 21, 1988), believes the rate at which the universe is expanding at ever-increasing distances is higher than what is commonly accepted. If true, the universe is far younger than many astronomers believe.

Tully's work, which is based on his own computer models and the known recession velocities of distant galaxies, assigns a value of between 85 and 95 km/sec/Mpc to the distance-velocity ratio that expresses the rate at which the universe's expansion velocity changes with distance. This ratio is usually expressed in kilometers per second per megaparsec (km/sec/Mpc). (A megaparsec is 3.26 million light-years.)

Astronomers are divided over what the Hubble constant really is. Some quote 50 km/sec/Mpc; others quote as high as 100 km/sec/Mpc. The main source of the dispute lies in the uncertainty of the distances to remote galaxies. Refinements in distance measurements for nearby galaxies have reduced Hubble's original value, first deduced in 1929, of 500 km/sec/Mpc. But uncertainties in distance determination methods — especially for objects at great extragalactic distances — still leave the value for the Hubble constant in doubt by a factor of 2.

Nevertheless, the Hubble constant is the only hope astronomers have of finally measuring the size and age of the universe. Astronomers have assumed that the Hubble constant is the same for all galaxies. However, in measuring the distance-velocity ratios of fifteen clouds of galaxies out to 100 million light-years, Tully found that the ratio is about 63 km/sec/Mpc for nearby galaxy groups and rises to as much as 95 km/sec/Mpc for more distant groups.

The discrepancy, said Tully, is due to the gravitational drag of dense clouds of galaxies in our vicinity. A galaxy's speed through the universe depends on the expansion rate as well as the gravitational pull of neighboring galaxies. Thus, dense clouds of galaxies do not expand as rapidly as less dense clouds.

Tully notes that about 99 percent of all nearby galaxies lie in clouds. Most galaxies within 32 million light-years lie in either the Coma-Sculptor Cloud (sometimes referred to as the Local Cloud), which contains the Milky Way, or a branch of galaxies called the Leo Spur. These clouds of galaxies, Tully said, probably contain enough mass to retard the expansion of nearby galaxies. Historically astronomers who have favored lower values of the Hubble constant usually based their results on the velocities of galaxies in these clouds.

If the correct value for the Hubble constant is indeed as high as 95 km/sec/Mpc, then the universe must be about 10 billion years younger than the currently quoted age bracket of 15 billion to 20 billion years. Unfortunately, this age strongly conflicts with the age of the oldest globular clusters, which is about 18 billion years. Tully, whose area of expertise is the distance scale, offers no resolution for this problem in his paper.

IAU STUDIES HAZARDS TO ASTRONOMY

Optical, radio, and amateur astronomers are losing their view of the universe because of rapidly proliferating artificial sources of interference. Over a hundred astronomers met to discuss these threats to astronomy at the International Astronomical Union's Colloquium 112 on "Light Pollution, Radio Interference, and Space Debris," held in Washington, D.C., on August 13-16.

According to organizer David Crawford of Kitt Peak National Observatory, this was the first meeting to bring together astronomers from around the world with lighting engineers, lawyers, and government officials concerned with the dangers to astronomy. Unless these problems are solved, said Crawford in his opening address to the colloquium, "observational astronomy will end."

In the United States, light pollution is beginning to be controlled by municipal and county lighting ordinances, at least around major observatory sites such as Kitt Peak (near Tucson) and Palomar Mountain (near San Diego). Ordinances mandate use of low-pressure sodium lamps, shielding of bulbs, and timer control of advertising and display lighting.

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orado, has been the difficulty and expense of designing quality light fixtures. DiLaura has developed software for manufacturers that makes good lighting easier and less expensive to design.

Just as light pollution harms optical astronomy, radio interference harms radio astronomy. Radio telescopes are often located in remote valleys that act as natural shields to stray radio energy. Of growing concern now is radio interference from satellites. Because it comes from overhead, astronomers can't escape from it. However, satellite transmissions are regulated internationally by the International Telecommunications Union (ITU).

Marcus Price of the University of Arizona explained that the ITU is charged with "spectrum management," "an administrative process to manage the radio spectrum to allow all users to accomplish their purposes." The purposes of various users may conflict with those of radio astronomers.

According to Price, "Scientists have good representation and good access to policy making in the United States — at least we know when we're losing." However, he added, "the United States is only one country and has only one vote" in the ITU. Furthermore, as stressed by Tomas Gergely of the National Science Foundation, there is enormous pressure for the reallocation of bands of interest to radio astronomers.

Another threat to radio astronomy is radio noise from consumer products such as computers and hand-held calculators. These products emit radio energy, even though they should not, and are hard to regulate.

Probably the most discouraging reports presented at the colloquium had to do with objects in space. According to Donald Kessler of NASA, NORAD tracks some seven thousand manmade objects fairly equally distributed close to Earth. Only about 5 percent of these are operational spacecraft; nearly half are fragmentation debris. Not only does space debris leave tracks on astronomical photographs, but it will endanger space-based observatories when they are launched.

Astronomers also expressed concern over "frivolous" uses of space, such as the orbiting "light ring" proposed by French artists to commemorate the one hundredth anniversary of the Eiffel Tower. Rather than suppress artists' concepts for self-expression, University of California astronomer Roger Malina proposed that "astronomers must work with artists to create appropriate restrictions" to limit the damage to astronomy from space-based works of art.

Space News

THE BUSH/DUKAKIS SPACE RACE

One of the surprises of the 1988 presidential election campaign is that the space program has emerged as an issue. Republican George Bush and Democrat Michael Dukakis are discussing civilian space policy on the campaign trail and they have taken generally supportive positions regarding the program's future.

Both Vice President Bush and Governor Dukakis support the re-establishment of the National Aeronautics and Space Council, a cabinet-level panel designed to provide a high level of space policy review within the White House. They are also of one mind in supporting the construction of a replacement shuttle orbiter, diversified expendable launchers, and continued development of the Space Station.

Dukakis originally supported studying "low-cost alternatives" to a permanently manned station but switched his position after receiving a letter signed by sixty-five Democratic members of the House of Representatives that urged him to make a strong space program a prominent part of his campaign. One of the first tasks of the prospective Dukakis administration would be to review the space program in general and the Space Station in particular to "assure the success of these important efforts," according to a statement released by the Dukakis campaign.

In addition to his newfound support for NASA's Space Station, Dukakis also has endorsed stable funding for space science to support the *Magellan* mission to Venus, the *Mars Observer*, the *Advanced X-ray Astrophysics Facility*, and the *Hubble Space Telescope*.

In a speech delivered at the Marshall Space Flight Center in Alabama, Bush announced his support for the Mission to Earth goal of the Ride Report (see "Charting America's Future in Space," January 1988), the development of a heavy-lift launch vehicle, and further unmanned exploration of the Moon, Mars, and the outer planets.

The Republican Party's platform also includes a strong space plank that calls for a national commitment to a manned Mars mission around the year 2000 and continued exploration of the Moon, which echo goals set out in the Reagan administration's National Space Policy released last February. That policy is referred to as the "Reagan-Bush initiative," thus raising hopes that it will be carried forward by a Bush administration.
— *Thomas J. Frieling*

ORBITING 'SUPER OBSERVATORY' PROPOSED BY SOVIET UNION

Soviet astronomers are thinking big these days. At this summer's General Assembly of the International Astronomical Union held in Baltimore, Soviet delegates proposed an ambitious new idea for conducting astronomy in space: placing a multi-instrument observatory in orbit over the far side of the Moon.

Using the considerable capabilities of the Soviet Union's new heavy launch rocket, Energia (see Viewpoint, September 1988), the massive observatory would be assembled in low Earth orbit and then lifted into either a higher elliptical orbit around the Earth or to the L2 Lagrangian point beyond the far side of the Moon, a position that requires little energy to maintain and is protected from radio interference from our planet.

Preliminary ideas for the observatory's instruments include a radio telescope with an effective aperture of 400 meters, a 10-meter optical telescope, and an x-ray and gamma-ray observatory.

The Soviets emphasized that such a major facility would require broad international participation. One U.S. astronomer commented that the "super observatory" would need support from other countries because it would likely carry a price tag in the tens of billions of dollars.

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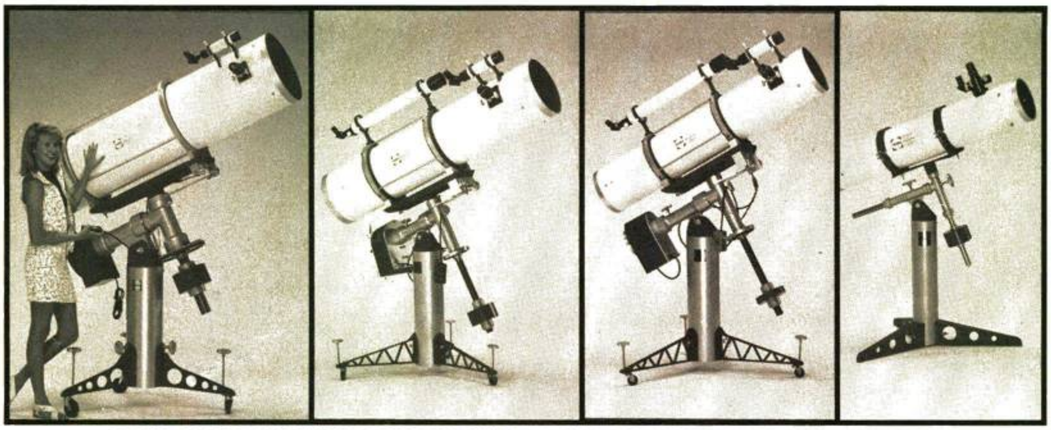

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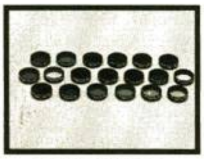

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Amateur News

AMATEURS GATHER AT STELLAFANE

Over two thousand amateur astronomers flocked to Breezy Hill in Springfield, Vermont, last August for the 1988 Stellafane convention. Many of the enthusiastic stargazers came from the northeastern United States, although others had traveled across the country and a few came from abroad.

Stellafane, Latin (sort of) for "shrine to the stars," is the oldest annual gathering of amateur astronomers in the world. With the exception of the World War II years, telescope makers and stargazers have gathered at Stellafane for fifty-two meetings to talk, show one another the telescopes they've made, and observe under the (usually) clear skies of south-central Vermont.

On Friday morning, August 12, Breezy Hill began filling up with telescopes and people. By Friday evening hundreds of amateur astronomers had arrived and filled the area, and the Springfield Telescope Makers, the host astronomical group, had its hands full managing the swarms of people.

On Friday night attendees split their time between talking with other amateurs, watching for Perseid meteors, and listening to the informal "tent talks."

DOZENS OF TELESCOPES, including a portable observatory (center), were the focus of interest at the 1988 Stellafane convention in Springfield, Vermont, last August.

This year's tent talks, so-called because they're held under a huge tent, ranged from astronomy-as-big-business to observing projects like March's solar eclipse and the recent increase in solar activity. Time after time, amateurs stood up and showed with pride the slides they had been waiting to show for months.

Telescopes displayed this year included both simple and elegant designs. One of the finest examples of craftsmanship was exhibited by Alan French. His 8-inch f/11 refractor rested on a large, homebuilt tripod that made the scope a Dobsonian refractor. Another refractor mounted as a Dobsonian was shown by Larry Manuel of Seeley's Bay, Ontario.

The show stopper, however, was an entire portable observatory brought by Bill Volna of Minneapolis, Minnesota. Looking something like a Caterpillar Tractor cab sitting on a rotating platform, the observatory featured a 6-inch refractor attached to one side with a prism that diverts light from the telescope inside the observatory. One or two people can sit inside and move the telescope anywhere in the sky while observing in comfort. For a complete report on the telescopes at Stellafane, see the fall issue of *Telescope Making*.

On Saturday afternoon the sky clouded and that night it drizzled, so Stellafaners didn't get a chance to use their scopes. But the crowd got a special treat: Clyde Tombaugh. Tombaugh walked to the speaker's platform amidst thunderous applause. Why? He's the amateur's amateur — the amateur who made good. Tombaugh's talk about how he discovered Pluto and what it was like to be at the focus of such an important discovery captivated the audience.

ASTRONOMICAL LEAGUE MEETS IN OMAHA

Two hundred amateur astronomers from across the United States convened for ALCON 88, the annual convention of the Astronomical League, at Council Bluffs, Iowa, July 27-30. The program included amateur paper sessions, a full day of papers presented by members of the Association of Lunar Planetary Observers (ALPO), an astronomical quiz tournament dubbed the ALCON 88 Star Bowl, a seminar on the astronomical use of microcomputers, and a visit to Phil and Margaret Heflin's Starlight Hill Observatory twenty miles north of Omaha.

Opening the meeting was David Crawford of Kitt Peak National Observatory and one of the founders of the International Dark-Sky Association (see AstroNews, August 1988). Light pollution is of crucial concern to all astronomers, Crawford stressed, and it's a problem that amateur astronomers can have an effect on. Crawford urged all amateur astronomers to become actively involved in fighting light pollution.

"Wasted light costs the United States $1 billion each year," said Tim Hunter, speaking on the high cost of light pollution. Hunter calculated the figure based on the average power use and the number of unshielded outdoor lighting fixtures in the United States. Hunter is the president of the International Dark-Sky Association.

A guest of the convention was John Dobson of the San Francisco Sidewalk Astronomers and inventor of the Dobsonian telescope. Dobson and other local amateurs polished an 8-inch telescope mirror during the four-day meeting. Onlookers were impressed with the speed and efficiency of Dobson's unusual mirror-making methods.

ALPO presented its Walter Haas Award to John Westfall for his pioneering visual photometry of Saturn's rings. Haas is the founder and long-time president of ALPO. By observing a stellar occultation, Westfall detected the fine structure of Saturn's rings decades before *Voyager* reached the ringed planet. Said Westfall, "I'm not sure one should be rewarded for doing what one likes to do," but he nonetheless accepted the award.

The outstanding accomplishment by a small astronomy club was the highlight of the convention. Member Jim Blair told how the four-year-old Southeastern Iowa Astronomy Club refurbished a vintage 12-inch f/15 Alvin Clark refractor and installed it in a new observatory. "We were in the right place at the right time," said Blair. The project began when club members discovered that the local high school had no use for the telescope housed on the roof of the school building. County conservation personnel interested in developing an astronomy program donated land, the school board donated the telescope, and the John H. Witte Foundation funded the construction of the observatory. Club members refurbished and restored the telescope, built the dome and its adjacent classroom, and now operate the completed observatory.

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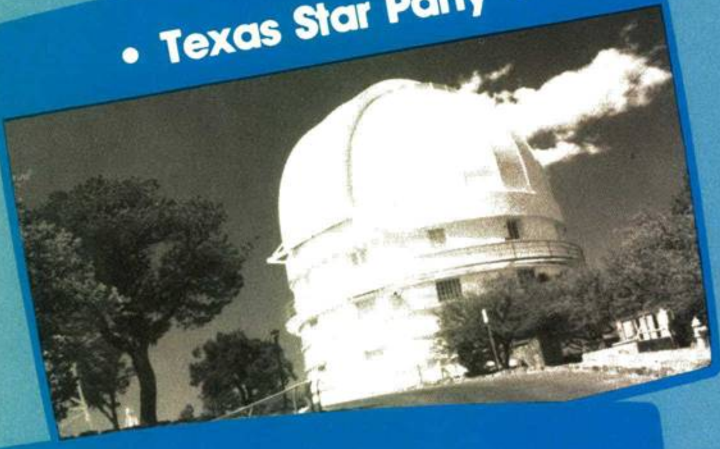

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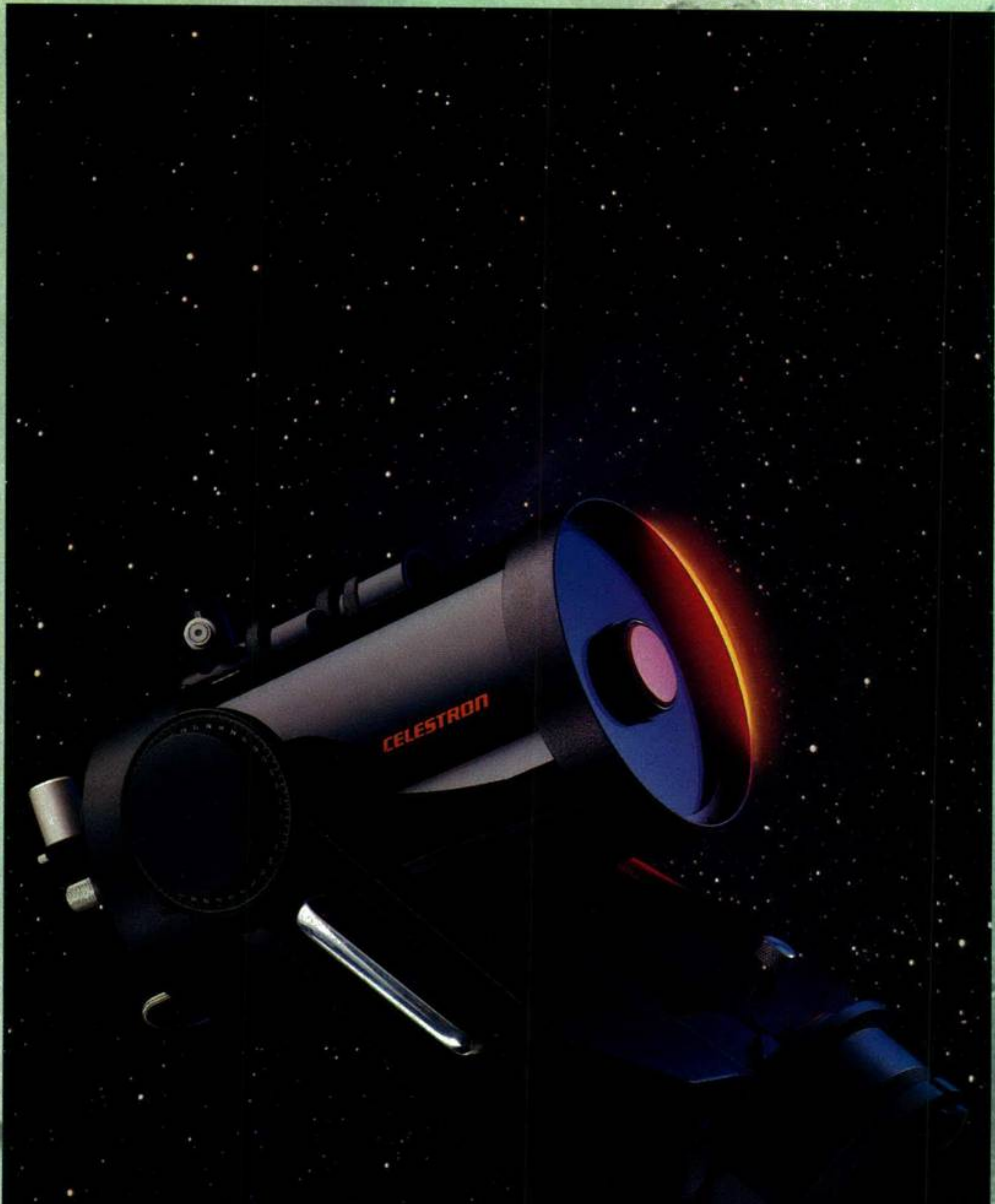
THE BEST GETS BETTER. Introd



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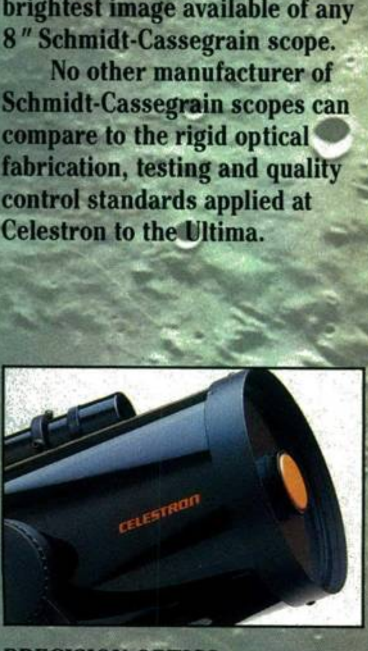

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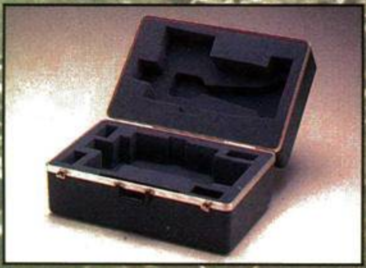

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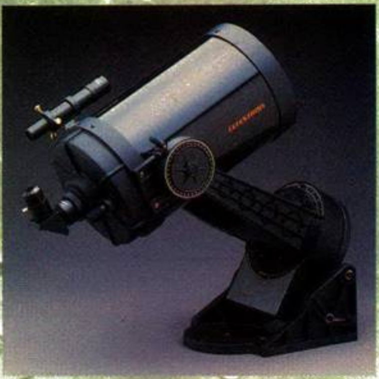

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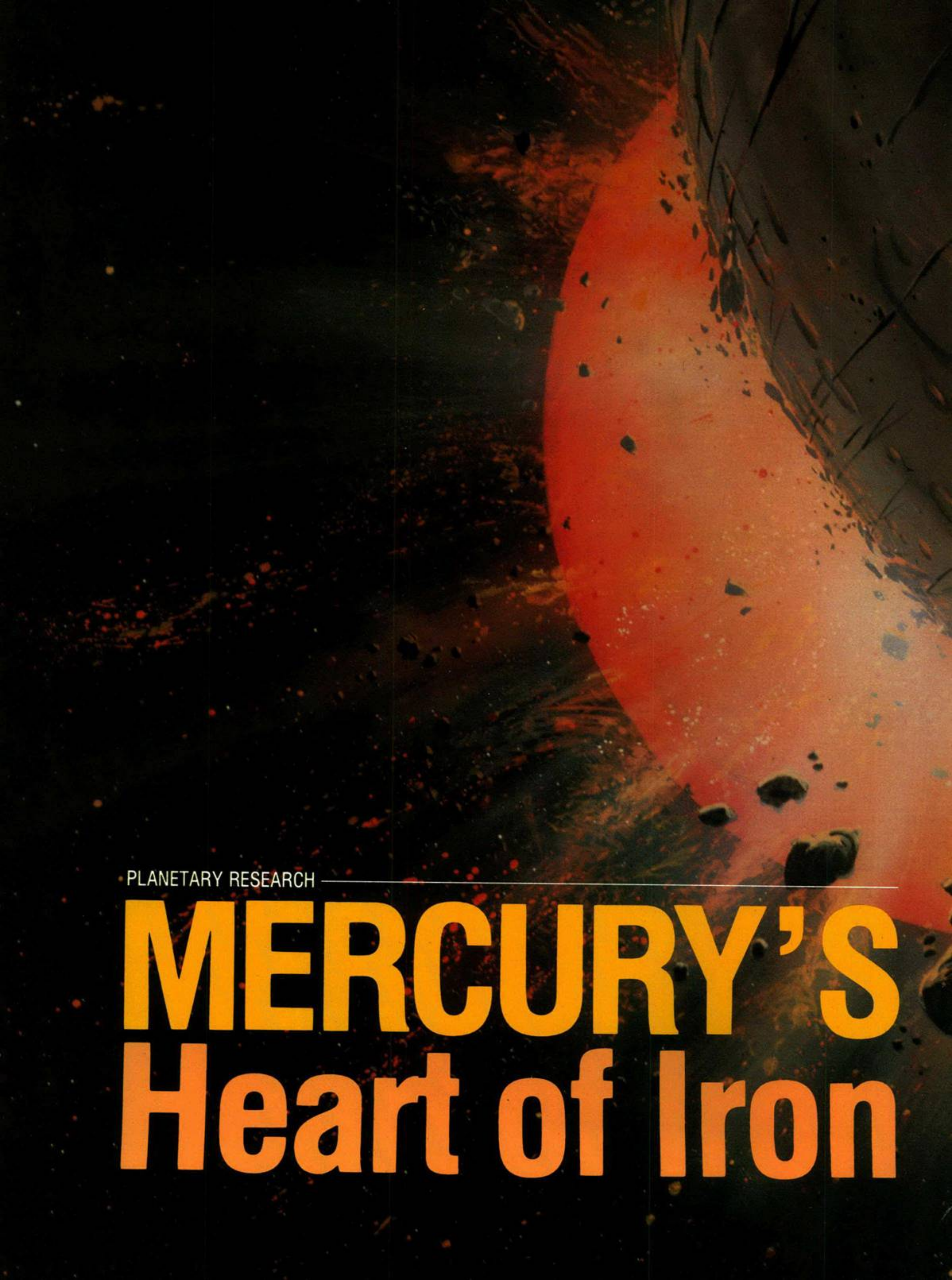
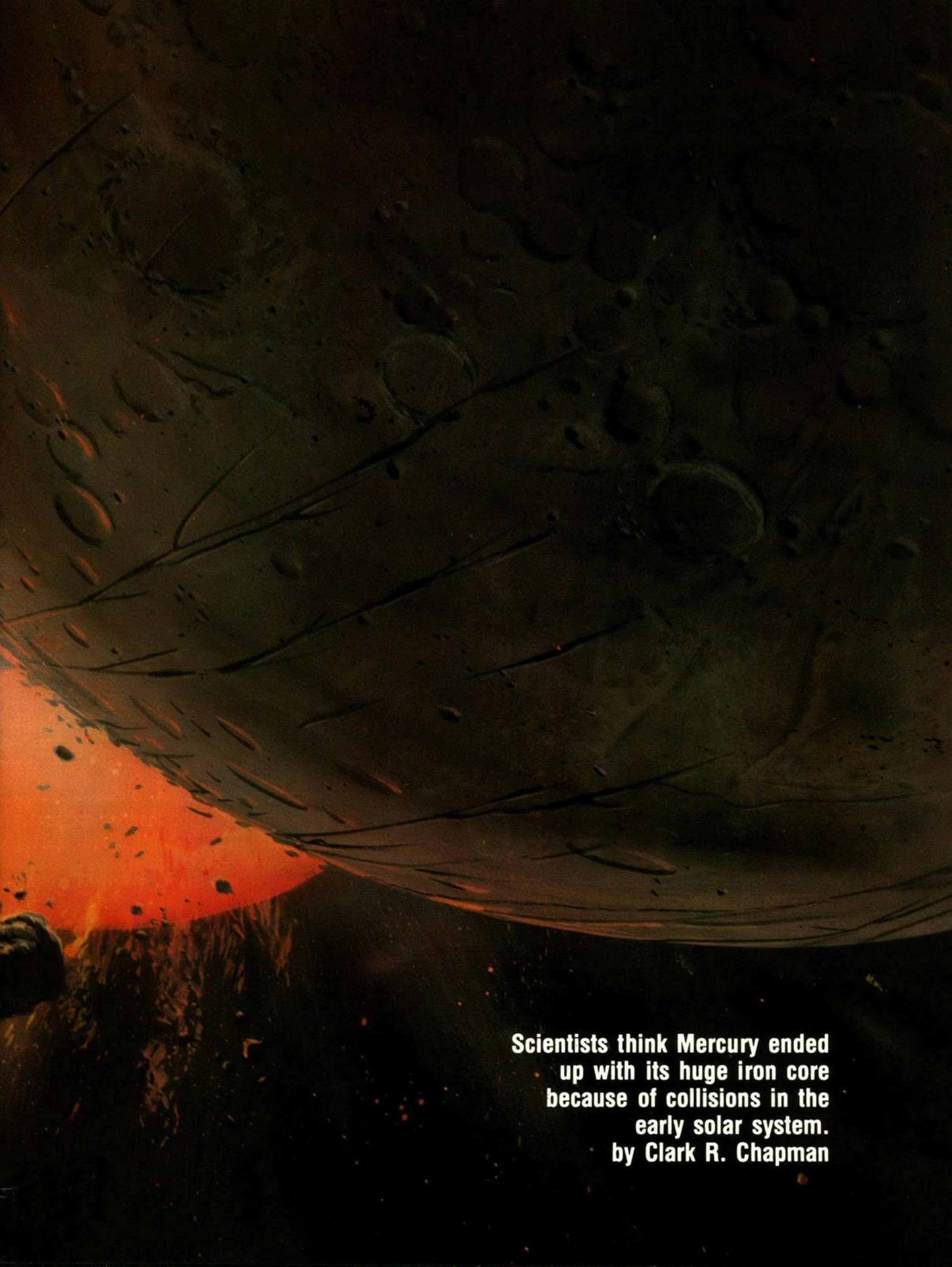


PLANETARY RESEARCH

MERCURY'S Heart of Iron



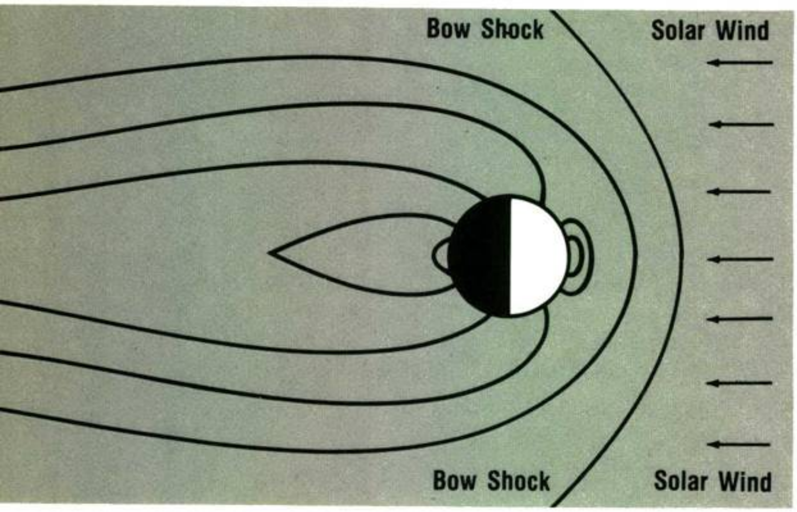
Scientists think Mercury ended up with its huge iron core because of collisions in the early solar system.

by Clark R. Chapman

The planet Mercury is appropriately named for the fleet-footed god. It seems to be continually running away from us, trying to hide its secrets. Visible for a brief time just before dawn in late October and early November, Mercury will vanish again into the glare of sunrise almost before you can see it.

Symbolic or not, Mercury's elusiveness has long presented astronomers with great difficulties. For nearly a century they were fooled into thinking that Mercury kept one face toward the Sun and that its "day" equaled its 88-day year. Then in the 1960s the 1,000-foot radio telescope at Arecibo, Puerto Rico, was used to bounce radar beams off Mercury. From changes in the returning signals, astronomers discovered that the planet spins once in 59 days, exactly two thirds of its 88-day year.

It has taken space age techniques to rip away the shimmery veils of misunderstanding that shroud the innermost planet. Now, more than a decade after its first-and-only spacecraft visit, planetary scientists have absorbed the data from that flight — and are posing new questions with answers that call for a return to Mercury.



JUST LIKE EARTH'S, Mercury's magnetosphere has north and south poles, but while its polarity matches Earth's, its field is only a hundredth as strong.

A Torrid World of Mysteries

The one spacecraft to visit Mercury, *Mariner 10*, made three passes in 1974-75 after flying by Venus en route. *Mariner*'s telescopic cameras showed us close-ups of a crater-scarred world that looked much like the Moon. But Mercury was hiding its true nature once again. Its moonscape is actually just a facade that shields its most significant trait: Mercury is a metallic planet.

Mercury acts like a magnet — it even has a dipolar magnetic field like Earth's — and most of the body of the planet is made of iron. In fact, Mercury's bulk chemical makeup may be the most atypical of any well-observed body in the cosmos, except for a few small, unusual asteroids. Almost 70 percent of the planet's mass may lie in the metallic iron core, which has a diameter 75 to 80 percent of the whole planet. Like a crust of mud wrapped around a ball bearing, Mercury's rocky fraction is a comparatively thin shell surrounding the immense iron core. Earth and the other terrestrial planets are made mostly of rocks, have modest iron cores, and are surrounded by relatively thin atmospheres of the heavier gases. By this standard, Mercury is truly bizarre. How it got to be that way is the subject of considerable debate in planetary science circles.

Like a ball bearing wrapped in a crust of mud, Mercury's iron core encompasses 70 percent of the planet's mass.

Mercury's history, therefore, holds crucial clues to such mysteries as why the planets are as they are and why Earth has a Moon. The resolution of these issues will probably change profoundly what we think about the origin and early evolution of the solar system. But before we turn to the big picture, let's focus on Mercury itself.

Mercury is a planet of extremes. Because it is the planet closest to the Sun, the huge solar sphere looms in Mercury's daytime sky and singes the planet's surface with outbursts of energetic particles. Mercury endures the most extreme temperature changes of any planet: from nearly 750 kelvins at perihelic high noon — at which temperature lead and zinc would flow like water — to only 90 kelvins just before dawn. Mercury has the solar system's shortest year and, except for Pluto, is the smallest planet. Its orbit is the most eccentric and the most inclined except, again, for that of Pluto.

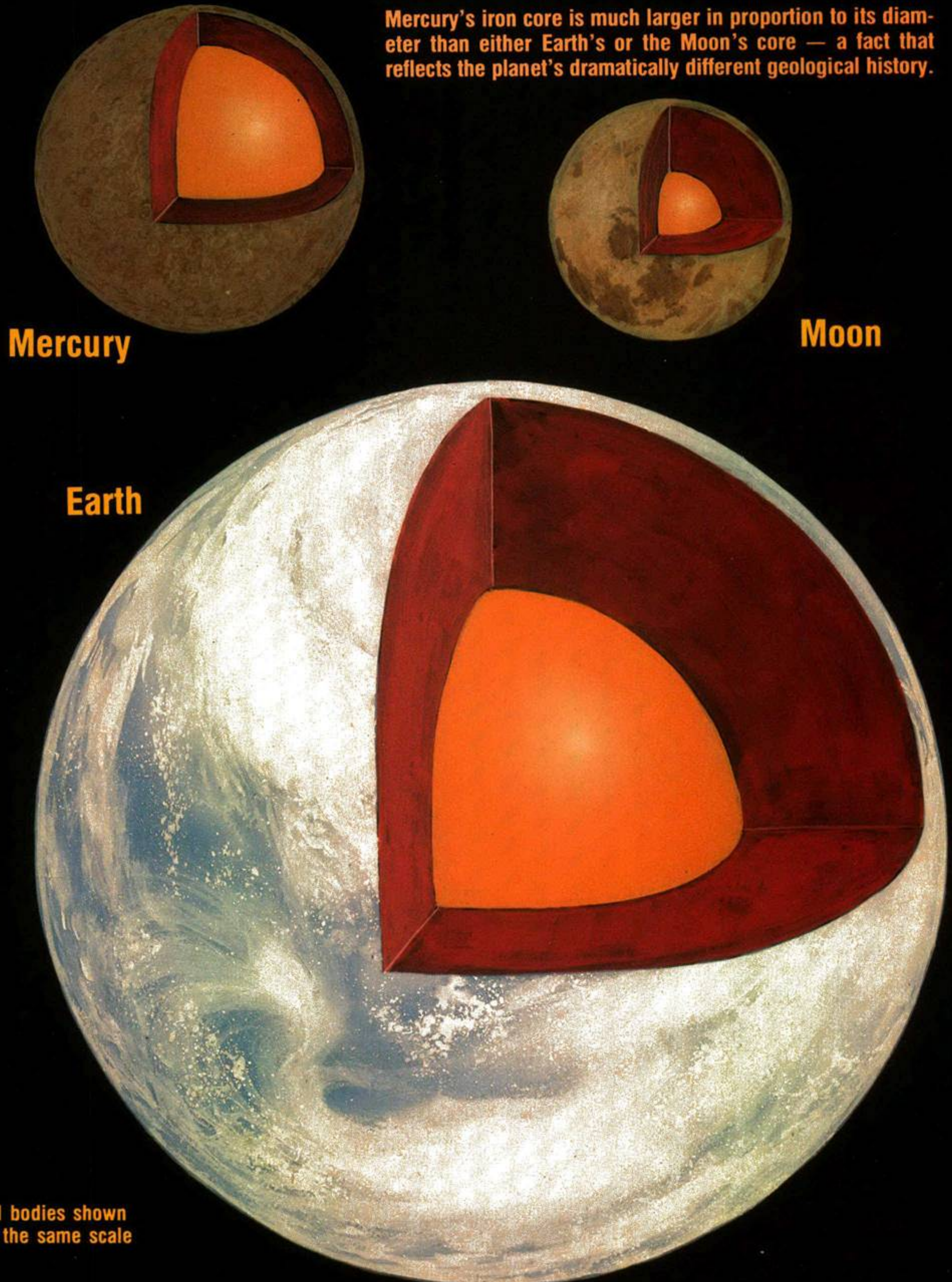
Mercury's surface is more ordinary. Over the eons it has been bombarded by asteroids and comets that have left countless craters scattered over the planet's landscapes. One enormous collision created the Caloris Basin, a crater the size of Texas (see page 26). There are flat, less-cratered terrains, where geologists think volcanic lavas once flowed. Volcanism ended long ago, however, and just like that of the Moon, Mercury's surface appears geologically dead. The only changes now come from the solar wind and very rare comet and asteroid impacts.

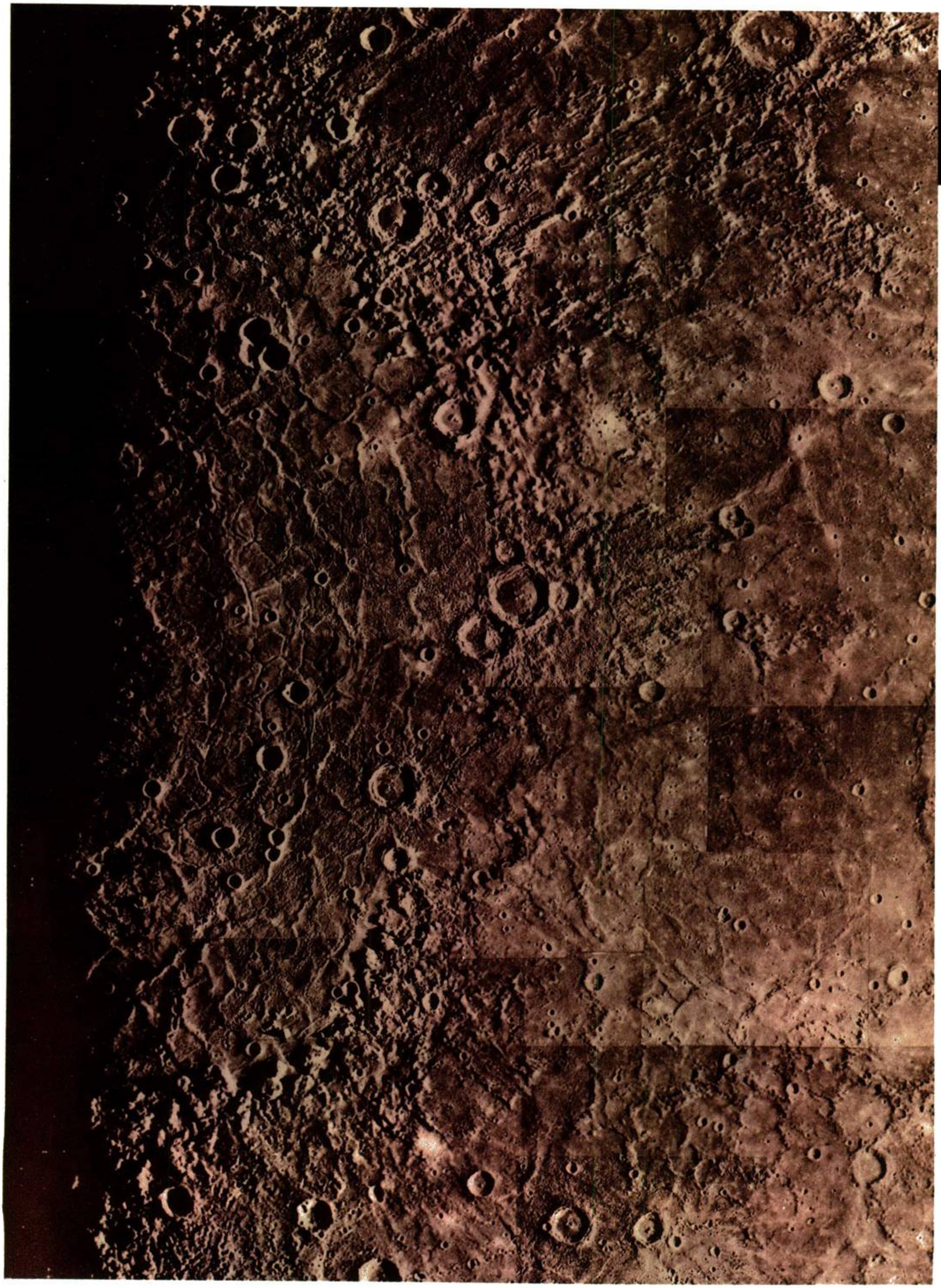
A closer look at *Mariner 10*'s pictures, however, reveals some distinctly Mercurian landforms. Distributed across the planet's surface are perhaps hundreds of lobate scarps (see page 29). These curvaceous cliffs, some more than a mile high, range from 15 miles to over 300 miles in length. Nowhere else are similar cliffs found in such profusion as on Mercury. It looks as if the crust of Mercury shrank and wrinkled, which is just what scientists believe happened. At some epoch in the distant past, Mercury's interior warmth began to wane, and as it cooled, the planet shrank the way almost any material does. The brittle, rocky crust buckled and cracked to produce faults and cliff faces.

But the most surprising finding of *Mariner 10* was Mercury's magnetic field. The planet's magnetism is only one hundredth as strong as Earth's, but the interaction of solar wind particles with the magnetic field forms a classical —although small — magnetosphere surrounding Mercury. The basic form of Mercury's field is quite

The "Core" of the Matter

Mercury's iron core is much larger in proportion to its diameter than either Earth's or the Moon's core — a fact that reflects the planet's dramatically different geological history.


Mercury
Moon
Earth
All bodies shown at the same scale



Caloris Basin is an impact crater the size of Texas.

Earthlike; a compass needle on Mercury would even point north. But the field is weak, and at times the solar wind may directly strike the surface of Mercury instead of being diverted around the planet as is true for Earth.

Beyond the traits of the magnetosphere, however, we find a crucial and more puzzling question: Why should Moonlike Mercury possess any magnetic field at all?

For one thing, Mercury rotates very slowly, which inhibits the creation of a magnetic field — or so theorists have thought. More important, the ancient age of the lobate scarps (attested to by studies of the relative number of craters they intersect) seems to imply that the planet's internal heat engine ran down long ago. This means there would be little chance of a molten core remaining and consequently no moving currents of core material to generate a field. Planetary scientists toyed with the idea that Mercury's rocks might be magnetized, preserving a magnetization induced by an ancient field existing when the rocks first formed. But it's highly unlikely that such a field would have the strength of even the weak one seen. The conclusion seems inescapable, therefore, that at least a thin zone of Mercury's core is still molten.

This idea has been accepted by most researchers only in the last few years. Although present planet-formation theories all agree that bodies like Mercury must have formed hot, simple physics shows that such small bodies would cool rapidly. A big planet can remain thermally isolated from its environment much longer than a small one can, just as a large block of ice melts more slowly than an equivalent amount in the form of ice cubes. While scientists readily understand how the modest radioactive heating within our planet keeps Earth warm, similar heat generated within Mercury would be conducted quickly throughout the small planet's thin, rocky layer and radiated into space. In fact, Mercury probably has even less heat-producing radioactive potassium-40 than Earth does, because potassium resides in rocks and Mercury is a rock-poor, metal-rich planet.

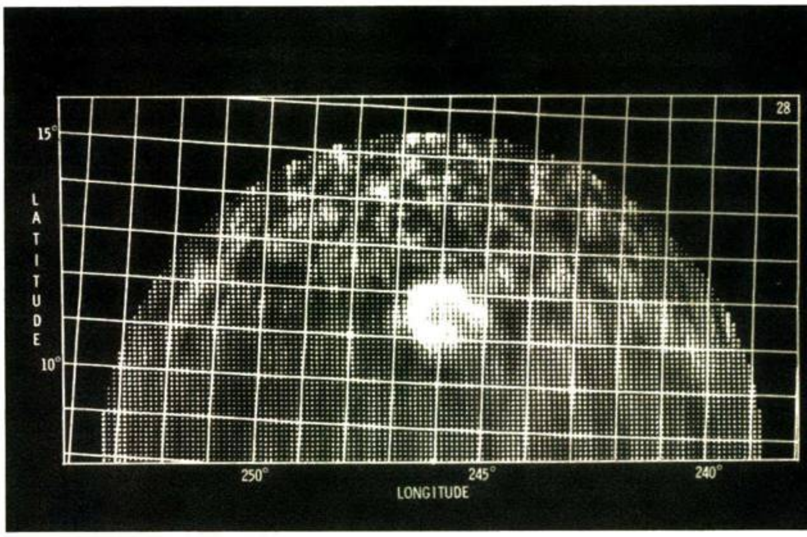
Apparently the answer is not that Mercury somehow has remained unexpectedly hot inside but rather that its metallic core may be partly molten at unusually low temperatures. The core might contain impurities like sulfur that would drastically lower the temperature at which the metal would solidify. Working as a kind of planetary antifreeze, sulfur could keep an outer shell of Mercury's core fluid, permitting dynamo motions to create a magnetic field, even though the planet's interior is not very hot.

Since *Mariner 10*'s investigations a decade and a half ago, there have been no spacecraft visits to Mercury. But research on the planet has continued, thanks to ever-improving ground-based radars and telescopes. More powerful radars can now probe the topography of Mercury with ever-improving clarity. Although *Mariner 10* photographed only one side of the planet, crude geological studies concerning the heretofore unseen side can now be done, based on the radar data (see below). Few insights have been obtained so far from the Mercurian radar echoes, but additional improvements at radar observatories like Arecibo may yield spectacular maps of the unseen side before any spacecraft mission can be planned and launched to the planet.

MOUNTAINS RING the Caloris Basin, scene of a giant impact. Shock waves fractured the rocks here and traveled straight through the planet to disrupt the landscape on Mercury's opposite side.

Air So Thin It's Hardly There

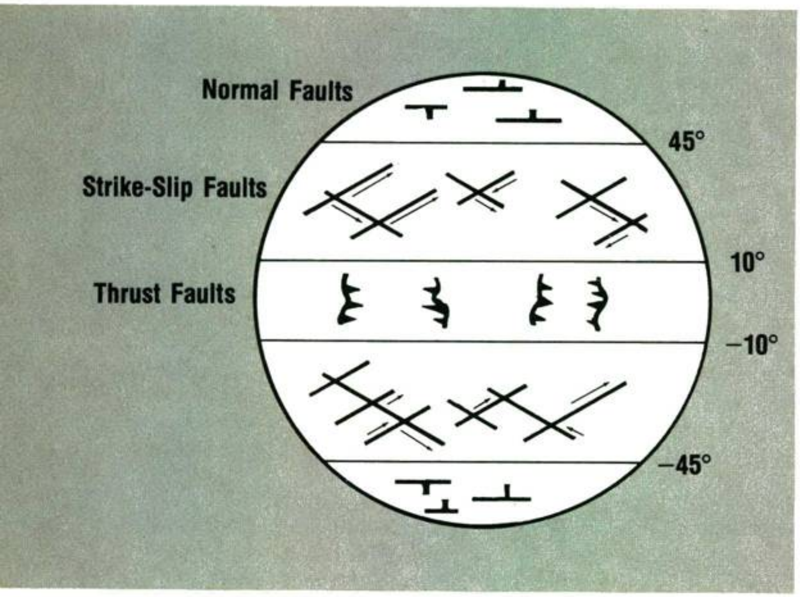
Before the 1960s astronomers thought clouds were drifting across Mercury's surface because the vague surface features visible in telescopes would disappear from time to time. Then radar studies revealed that observers had been assuming the wrong spin period for Mercury. When the old observations were re-examined in light of the correct spin, the need to invoke clouds as an explanation vanished. Just as well too, because theoretical considerations made it difficult to understand how Mercury could have much atmosphere to speak of. After all, Mercury is a small planet in an extremely hot environment. For the same reason that the Moon cannot hold onto an atmosphere, Mercury can do so even less. When astronomers once again began to write papers about Mercury's atmosphere in the decade before *Mariner 10*, they were describing the behavior of atoms and ions in a near vacuum. Because there was no observable atmosphere, the analysis was entirely theoretical.



RADAR PROBES the unseen hemisphere of Mercury to reveal an 85-kilometer-diameter crater (white circle, center) with a probable central peak.

Then, just three years ago, Mercury's next-to-nothing atmosphere suddenly aroused new interest when two NASA Johnson Space Center scientists discovered spectral emission lines. These bright lines in Mercury's spectrum come from sodium in the thin Mercurian atmosphere. Later, lines caused by potassium were detected and measured as well. A decade earlier, similar unexpected spectral features were discovered on Jupiter's moon Io — one of a series of unexpected revelations about Io that culminated in the discovery of that body's remarkable sulfurous volcanism. Planetary scientists do not believe Mercury's atmospheric emissions will prove to be quite so revolutionary. The lines are produced by a very small density of atoms: at most, Mercury's atmosphere is only a trillionth as dense as Earth's — nearly a perfect vacuum by almost any standard.

Because Mercury's thin atmosphere can be detected and monitored from Earth, however, astronomers can now use spectrographs to study Mercury's interaction with the solar wind and other traits previously thought to require on-site measurements by a spacecraft. For example, variations in the characteristics of the spectral lines — including differences when Mercury is at different places in its orbit — may tell us much about Mercury's sodium-ion-rich magnetosphere.



AS MERCURY LOST its primordial spin, stresses opened up fractures in its crust and created fault zones where later geologic activity created scarps.

The atmospheric emission lines may also enable us to study another Mercurian mystery, the planet's surface composition. The minerals that make up the surfaces of the Moon, the asteroids, Mars, and the outer planet satellites can be studied from broad absorption bands in the spectra of sunlight reflected from those objects. But Mercury's reflected spectrum is "bland" and shows no absorptions because of minerals. Perhaps the planet's surface is made of minerals that just happen to be spectrally featureless, but it is also possible that interactions between surface minerals and the impinging energetic solar wind and magnetospheric particles have neutralized any inherent spectral features by blackening the mineral grains.

Astronomers have long wanted to know whether the chemistry of Mercury's rocks is like that of Earth or various types of meteorites. There is hope that some questions about Mercury's chemical makeup can be addressed by studying the atmospheric emission lines.

Curvaceous cliffs, some over a mile high, snake across Mercury's craterscape.

For example, if astronomers understand how sodium and potassium get into the atmosphere from the planet's surface, perhaps they can measure the brightness ratio between sodium and potassium lines and calculate the sodium-to-potassium ratio of Mercury's rocks. Comparing the result with that obtained for other planets may let us probe a little into Mercury's surface. At the moment, however, it isn't known whether the sodium and potassium are derived by erosion of Mercury's rocks or instead come from meteoric material that arrives on the planet's surface from interplanetary space.

Planetary Pinball

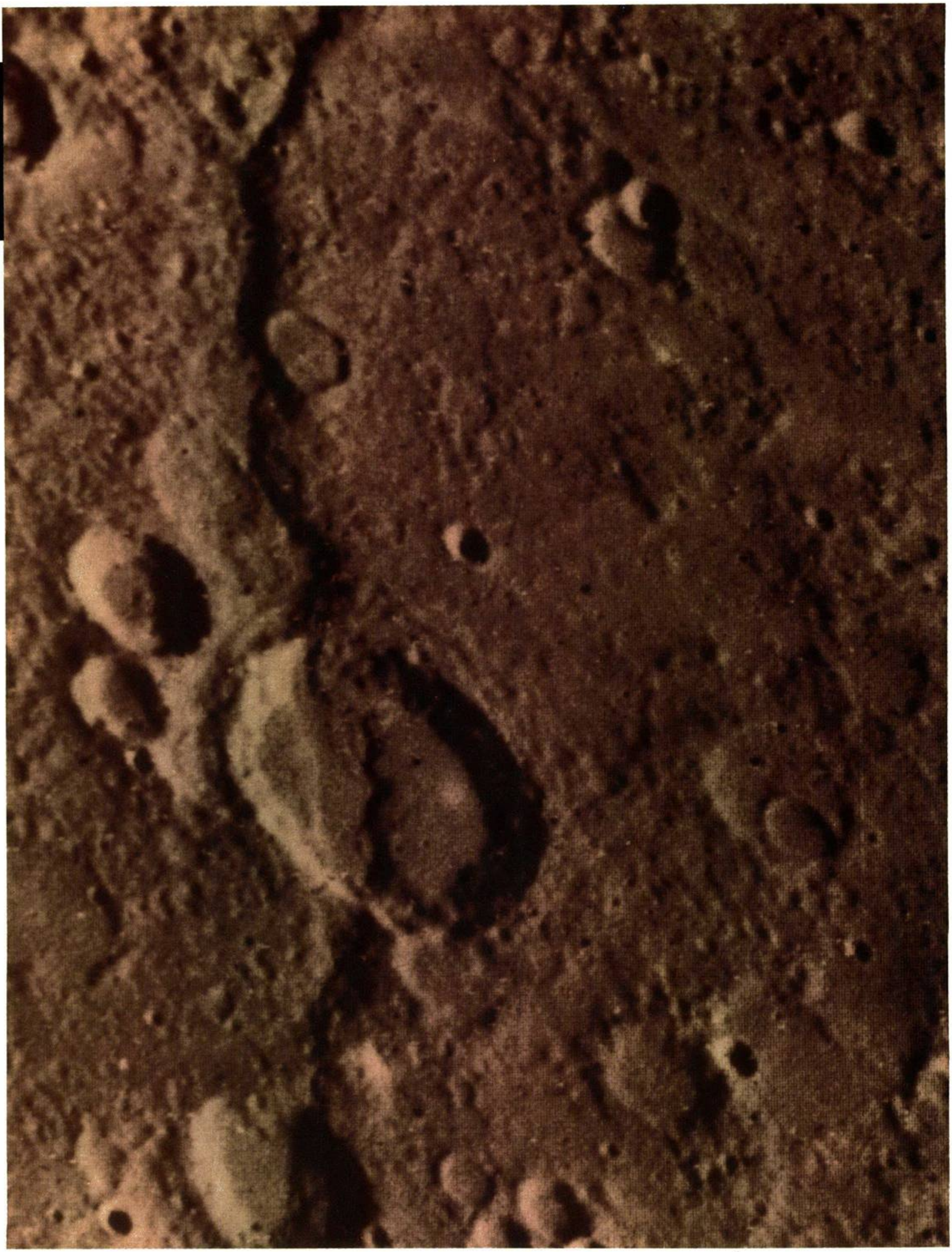
With only nine major bodies to deal with, planetary scientists are continually looking for patterns that might elucidate how the planetary system formed. One important pattern involves the variation in chemical composition with distance from the Sun. Evidently, rocky planets were favored in the inner solar system and gaseous planets in the outer system. In the early 1970s cosmochemist John Lewis (then at MIT) took this regularity a step farther and concluded that the differences between Mercury, Venus, Earth, and Mars could be explained by a simple yet elegant model that he called equilibrium-condensation.

It works like this. Imagine there was once a hot solar nebula, a vast disk of gas and dust swirling around the just-formed Sun following the collapse of an interstellar cloud. As the nebula cooled, the first grains to condense from the cooling gas would be those with high melt/freeze points: metals and certain high-temperature minerals. Next grains of ordinary rocks would condense out of the vapor. At lower temperatures still, ices would eventually form.

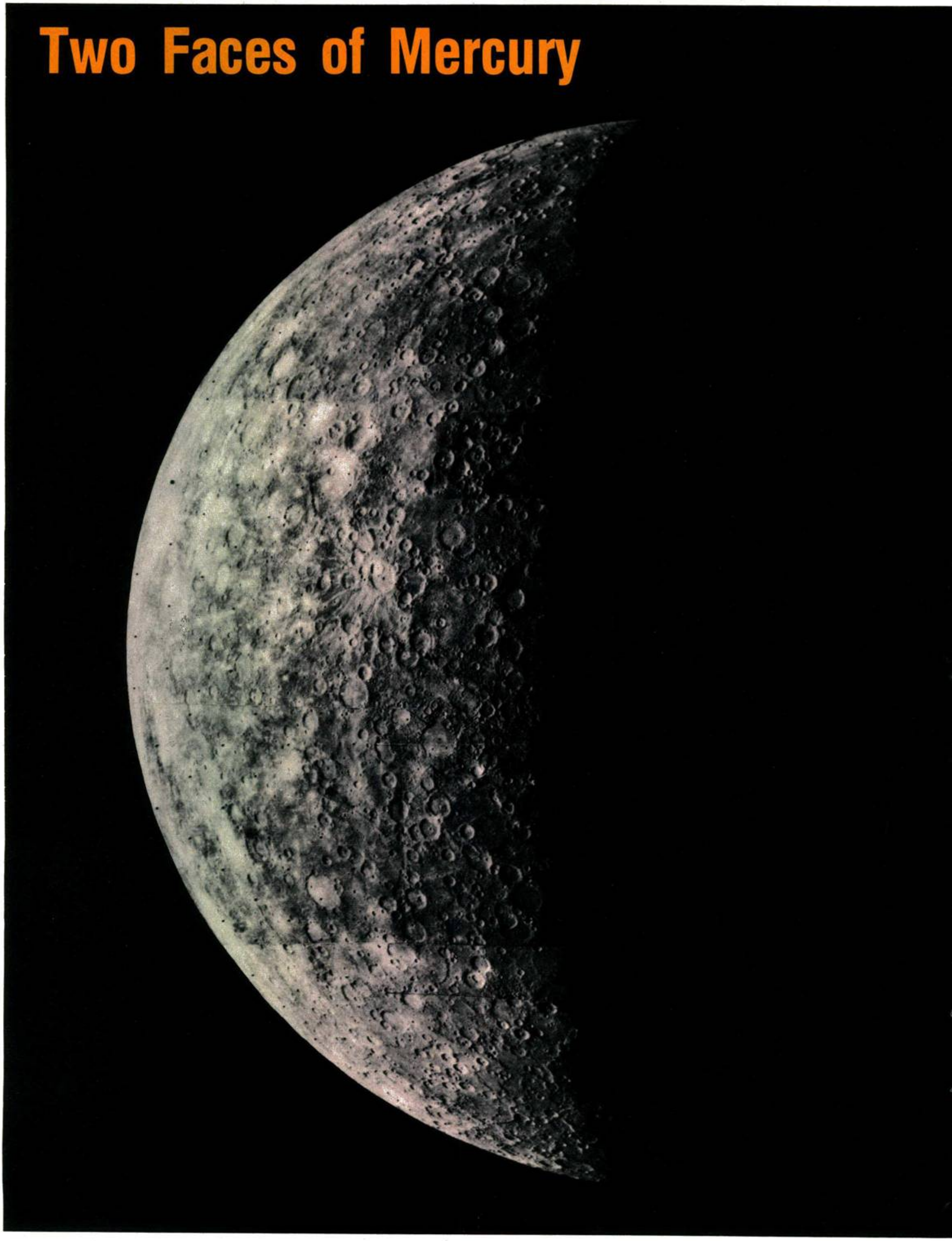
At some point in this sequence — while metals had condensed in the hottest part of the nebula near the Sun, but the whole suite of materials had condensed in the vicinity of Jupiter — the Sun flared up and blew away the gas. Each planet then formed from the condensates left behind at its respective distance from the Sun. In this case Mercury would consist predominantly of high-temperature condensates (mostly iron) and the more distant planets would be made of successively lower-temperature condensates. This basic model seemed to explain the bulk densities of the terrestrial planets.

Lewis' idea was important because it implied that the planets were made in a very orderly way. They were made almost entirely of materials that condensed out of the solar nebula at each planet's distance from the Sun. Materials from Earth's zone didn't mix with those in

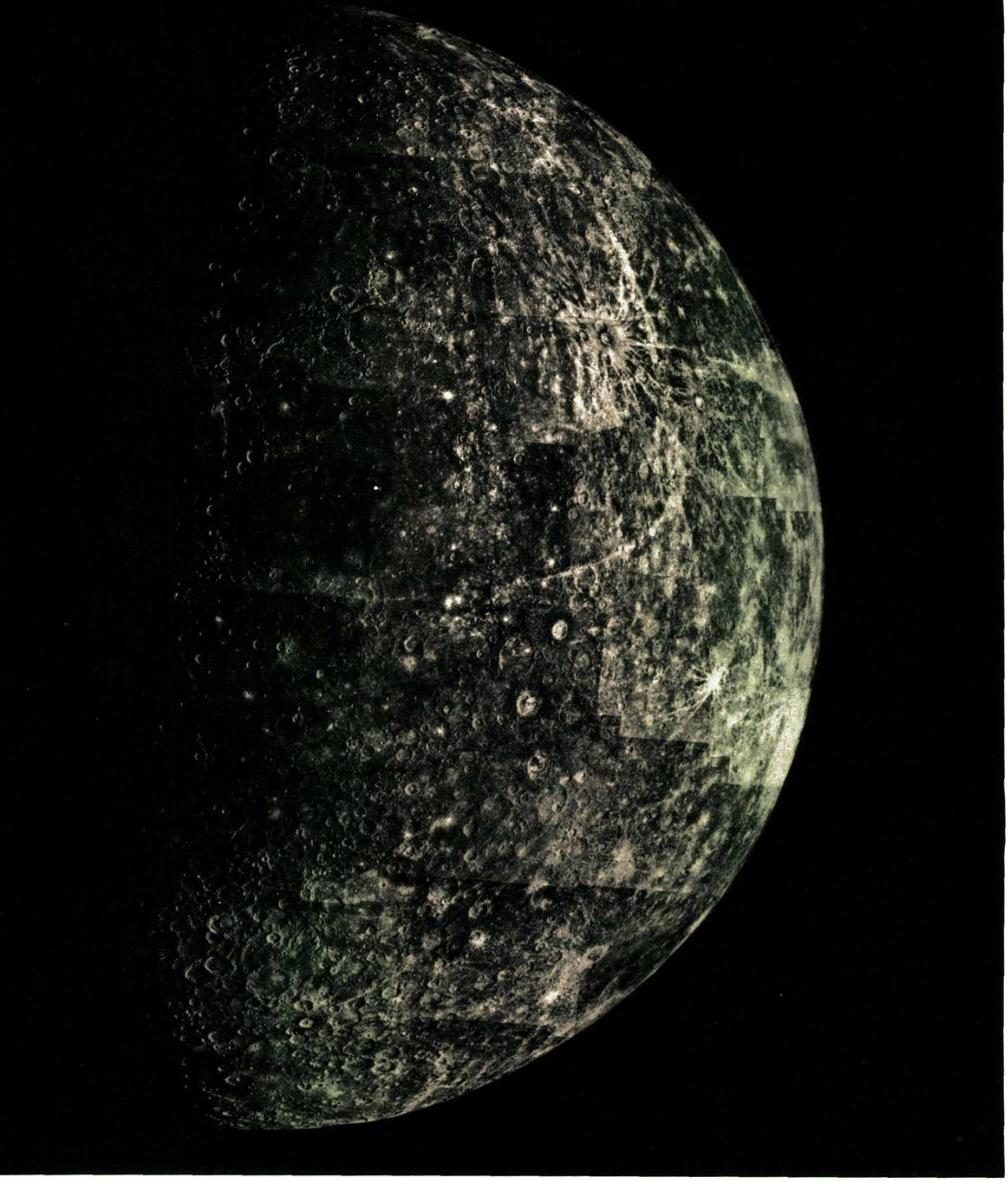
SLICING THROUGH CRATERS AND PLAINS, the Discovery Scarp marks where rocks were piled on rocks as Mercury cooled and shrank.



Two Faces of Mercury

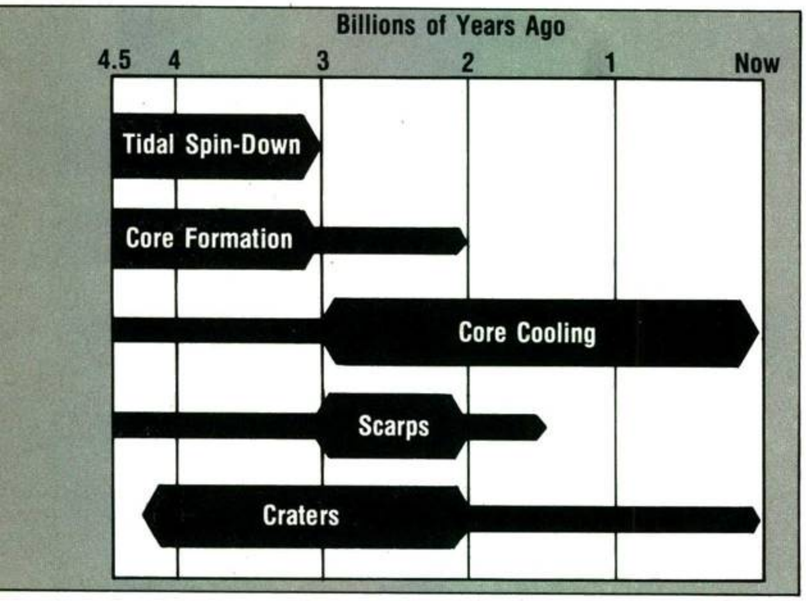


A cratered "moonscape" greeted *Mariner 10* on its inbound journey (left), but closer examination revealed important differences between Mercury and the Moon. Outward bound, (below) *Mariner 10*'s cameras snapped a Mercurian mosaic of craters, plains, and rays. In all, *Mariner* photographed about 45 percent of the planet.



Mercury's — nor did Venus ingredients end up out near Mars. Everything happened in a slow, regular way with the condensates all in chemical equilibrium with the nebular gas. Scientists could make precise predictions about the full complement of chemicals each planet was made of. One of Lewis' many predictions was that Mercury would have no sulfur; other predictions postulated different chemistries for Earth and Venus that seemed to explain slight differences in the bulk densities of these two planets.

Although Lewis' theory was very influential, further work uncovered ways in which reality doesn't follow the predictions. One was the "no-sulfur" Mercury. (We saw above that sulfur may be necessary to explain why Mercury has a still-active magnetic field.) This and other discrepancies have meant that over the last few years a major challenge has been raised against the Lewis theory, partly centering on the question of how Mercury formed. The protagonist for the new view is George Wetherill of the Carnegie Institution in Washington, D.C. Wetherill has been making calculations about how the planets can accumulate from their smaller precursors, asteroidlike planetesimals. His calculations show that planets probably do not grow in an orderly way. In fact, in Wetherill's view, Mercury's formation was wildly disorganized and catastrophic.



A TIME LINE FOR MERCURY shows processes operating over 4.5 billion years. A thick bar means significant activity, a thinner one denotes a diminished role.

Here is one possible way that Mercury might have formed, according to Wetherill's computer runs. About two dozen bodies, each with a third the mass of the Moon and made of rocks and metal, accumulated to form a proto-Mercury about twice as massive as Mercury is today. The bodies came either from near Mercury's present orbit or from beyond Earth's orbit. After about 6 million years, when the proto-Mercury was orbiting at about Earth's distance from the Sun, it happened to hit another small but growing planet. That violent collision was so energetic and released so much heat that the proto-Mercury melted throughout, and its heaviest elements — such as iron — sank toward the center and the lighter elements floated upward to form a skinlike rocky mantle at the surface.

Major impacts mark the boundaries of Mercury's still undated geological eras.

About 10 million years later, when the melted and differentiated proto-Mercury was located halfway between the modern day orbits of Earth and Mars, it collided with an even larger body — greater than half its own size — which impacted at a velocity of 8 miles per second. This enormous collision tore proto-Mercury asunder, stripping away most of its mantle and crust and leaving the core with only a thin, rocky covering. The ejected material was shot at high velocity into interplanetary space, never to return.

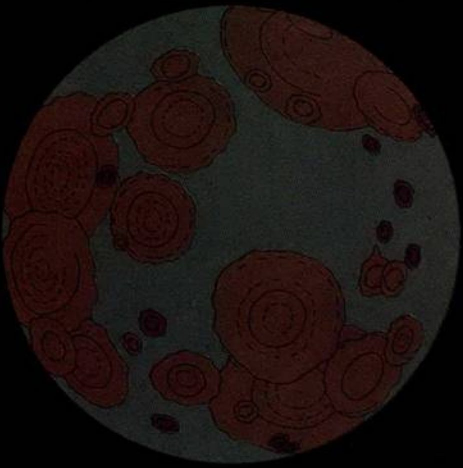
In one shattering collision Mercury thus became a metal-rich planet. Over the ensuing 18 million years, in Wetherill's calculations, Mercury wandered around the inner solar system. It was occasionally deflected by the gravity fields of other growing planets — including proto-Earth and proto-Venus — until it settled down into its present orbit close to the Sun.

This gripping scenario is only one of several that Wetherill has devised to account for Mercury's formation. Impacts are chance events and the reality may not have happened exactly that way. The important point, according to Wetherill, is that giant collisions were common in the early history of the solar system. There was widespread mixing of materials that originally condensed in regions anywhere from the present location of Mercury out to the asteroid belt.

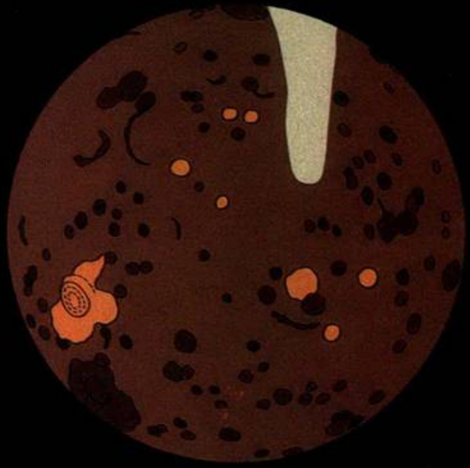
In Wetherill's view, the present day makeup of the terrestrial planets may be as much due to chance as to any orderly variation in the solar nebula condensates. From looking at Mercury as it is today, planetary scientists believe that the planet probably did get blown apart at a critical point in its formation. Proto-Earth, on the other hand, was lucky enough to grow to a larger size before it suffered the chance collision with a Mars-sized body that many scientists now believe created the Moon. Because Earth had grown so large by the time of that collision, gravity held it together for the most part. Only a small portion of its mantle was lost and nearly all the ejecta remained trapped in Earth orbit, where it ultimately coalesced to form the Moon.

Many other issues in planetary science depend on whether the chemical and physical processes during primordial times were orderly and systematic or were dominated by disorder and random catastrophic events. Is the apparent variation in composition of asteroids with distance from the Sun a relic of the early solar nebula or the result of more disorderly, later processing? How similar or different were the original compositions of the atmospheres of Venus, Earth, and Mars? Were colliding worlds common in the early history of the solar system? Was a giant collision responsible for nearly stopping Venus' rotation? Or for tipping Uranus on its side?

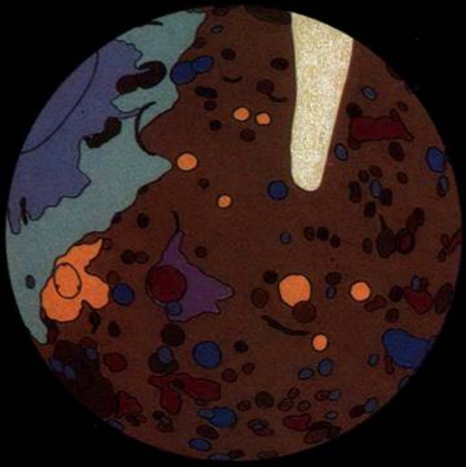
Mercury's Geohistory



Middle Pre-Tolstojan Time

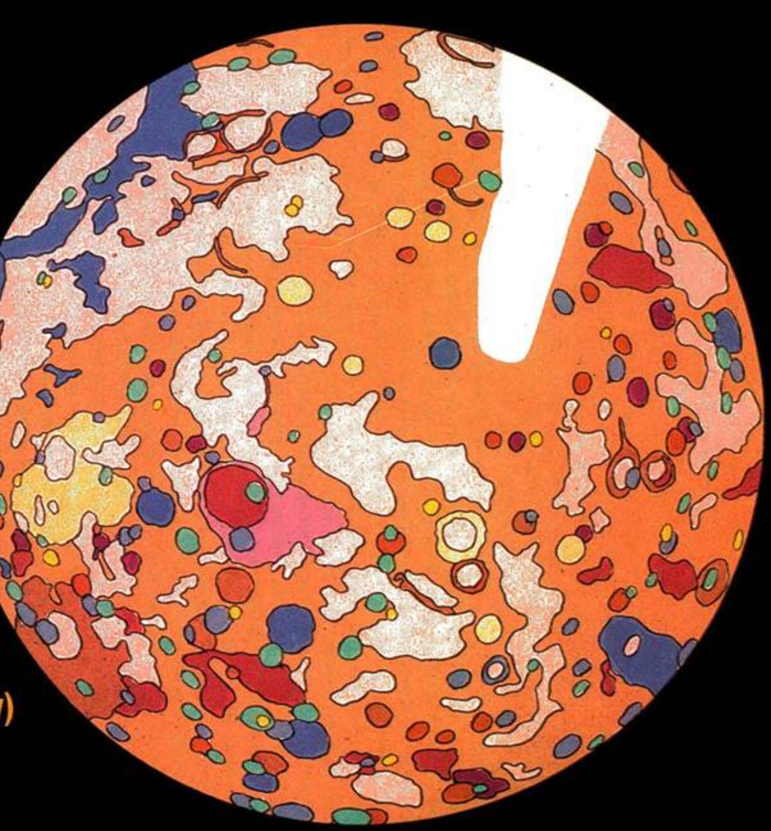


Early Tolstojan Time



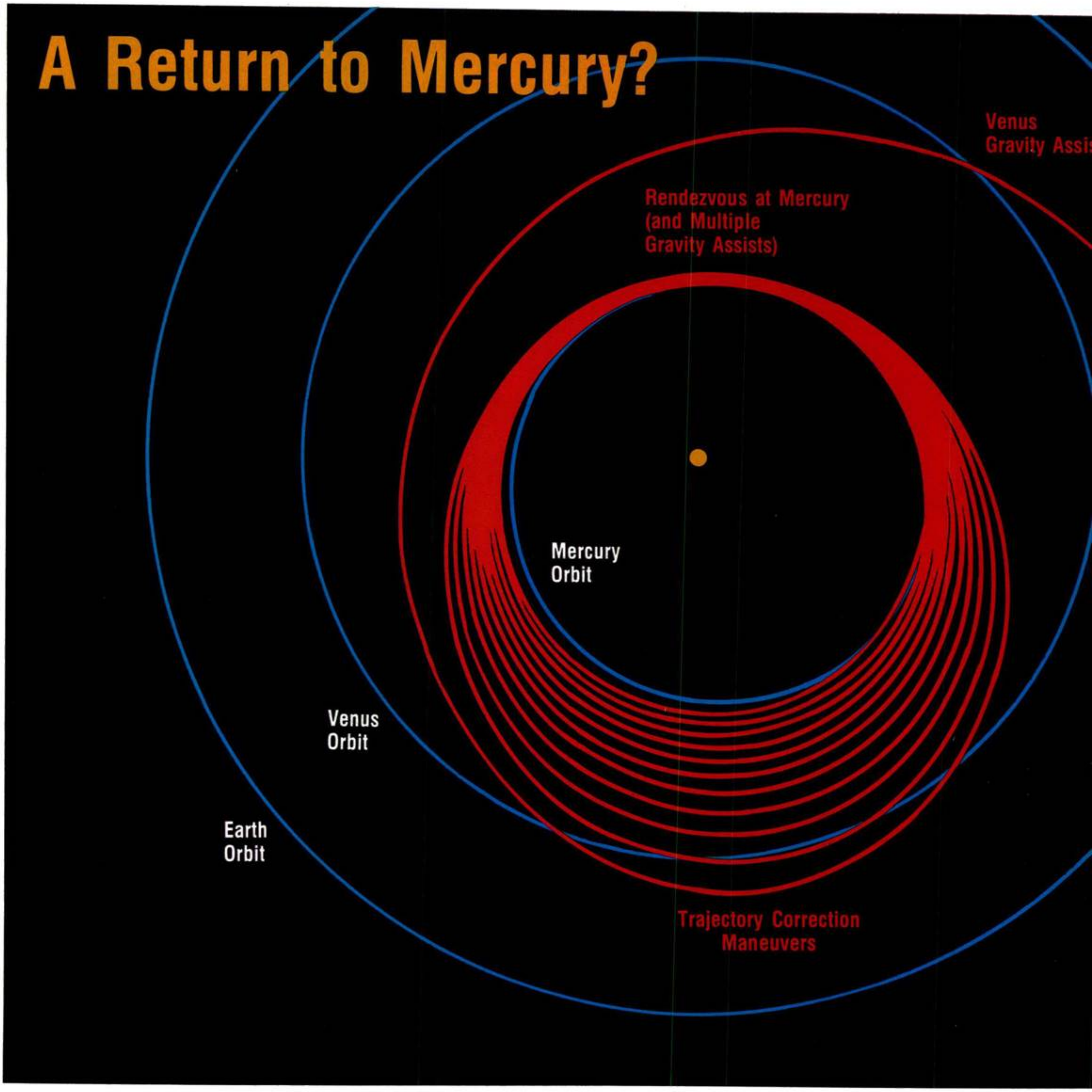
Early Calorian Time

No absolute dates exist for Mercury's geological epochs, but relative relationships are fairly clear, and each period is named for a crater or basin that characterizes it. Working from studies of the Moon, however, planetologists think the Caloris impact (a major watershed in Mercurian geology) occurred about 3.9 billion years ago.



Kuiperian Time (present day)

A Return to Mercury?



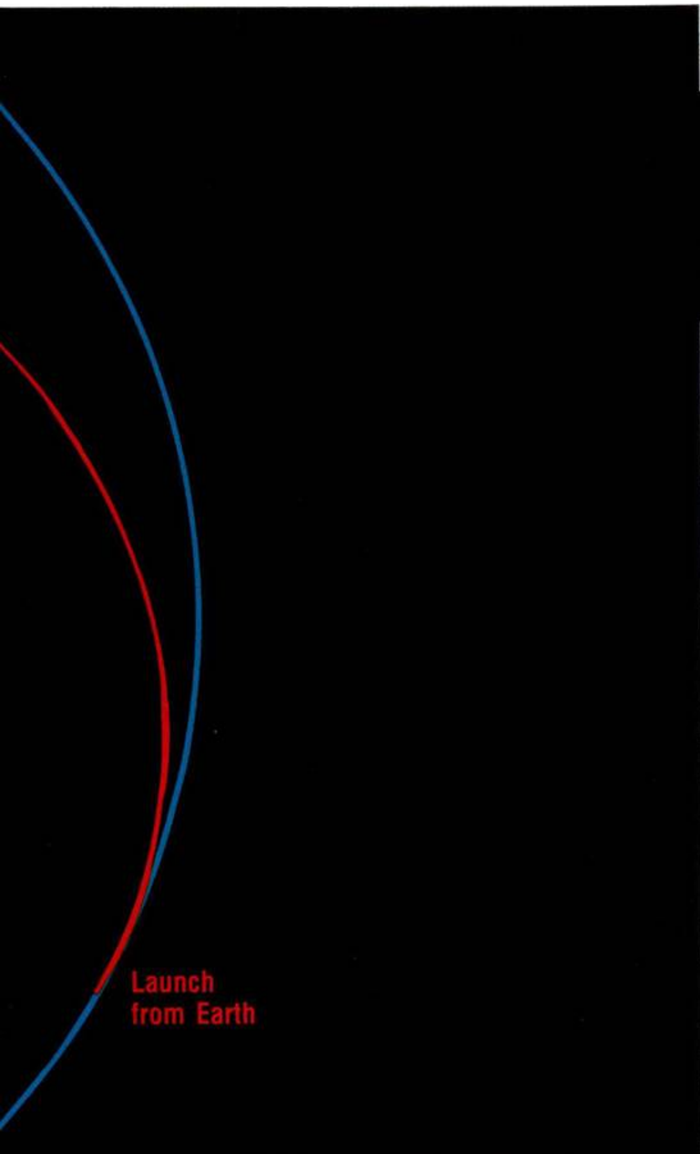
Some scientists are now convinced that the early history of the solar system was much more chaotic than we used to believe. Others still adhere to variations of John Lewis' orderly model, although Lewis himself has moderated his stand. Confirmation of what happened in Mercury's early history — which requires detailed study of the planet — will be only one of several approaches to answering these questions. But as the closest planet to the Sun and the one with the most extreme composition, Mercury will play a key role in furthering our knowledge of the solar system.

A Return to Mercury?

These are difficult times for the American space program. With planetary launches delayed for several years because of problems with the space shuttle and with explorations of comets, asteroids, and the Saturn system pushed beyond the turn of the century, it may seem unrealistic to think about return space missions to Mercury. This is especially so because the existing long-range plans of NASA's Solar System Exploration Division, as well as the announced plans of other space-faring nations, pay little attention to Mercury. But things may be brightening for our little metal planet.

Follow-up missions to Mercury were hindered in the late 1970s when the United States abandoned serious work on low-thrust propulsion systems, such as solar electric propulsion. At the time these seemed essential, because any significant improvement on the *Mariner 10 mission required going into orbit* around Mercury, and the chemical rockets then available were thought inca pable of making the trip. Second, it was somewhat daunting to think about designing a spacecraft to survive

A new mission to Mercury is vital to planetologists and space physicists.



High-thrust chemical propulsion and low-thrust ion propulsion both can send a new spacecraft mission into orbit around Mercury. Either approach involves flight times of a year or two and gravity assists from Venus and Mercury itself.

the high temperatures near Mercury.

A third obstacle was that the prestigious planetary committee of the National Academy of Sciences' Space Science Board, known as COMPLEX, contended that while further studies of Mercury and the Moon were important, they were less pressing than comparative studies of Venus, Earth, and Mars. In 1983 NASA's Solar System Exploration Committee reiterated this conclusion in its core program of planetary missions for the 1990s. Several years later a European proposal for a Mercury mission also failed to survive competition within the European Space Agency.

But the situation has improved, at least in a comparative sense. Chen Wan Yen, an engineer at the Jet Propulsion Laboratory in Pasadena, California, discovered several years ago that it was readily possible to send a chemical-rocket mission to Mercury orbit by using repeated gravity assists from Venus and Mercury itself. (Similar gravity assists, using Venus and Earth, will be used to get the *Galileo* spacecraft out to Jupiter.)

Simultaneously, the last decade has given mission planners confidence that spacecraft can function reliably over the several-year flight times that multiple-gravity-assist missions require. Without this confidence in the past, mission planners overlooked Mercury opportunities because a large number of successive encounters with Venus and Mercury were necessary to achieve orbit and flight times appeared to stretch too long for comfort. But from today's engineering standpoint, travel times to the inner solar system are brief and even a many-encounter flight to Mercury is still short compared with getting to the outer solar system. Solar heating? This too now looms as less of a worry than it did.

Finally, scientific interest in Mercury has grown significantly in the last few years, thanks to new discoveries and new thinking about Mercury's role in comparative planetology. The first scientific conference about Mercury in a decade was held in the summer of 1986 and a major reference book about the planet will be published this autumn as part of the University of Arizona's Space Science Series.

COMPLEX has also been reconsidering its exploration strategy for the inner planets. Although its report is not yet out, the report is expected to be more favorable to a Mercury mission than its recommendations of a decade ago. Meanwhile, the National Academy of Sciences has released a report on new directions for NASA in the next century and Mercury won the interest of numerous scientists from many disciplines. Mercury is vital not just to planetologists and space physicists. It is also an important observation post for solar physicists. And a mission to Mercury would provide excellent opportunities for refining our checks on the theory of relativity. In fact, NASA's Space Science Division has already formed a committee to study a possible Mercury mission and NASA's Planetary Division has begun considering Mercury as a possible target for a future Planetary Observer spacecraft.

There is renewed hope that both public and scientific interest in this unusual, metallic world will eventually motivate a new spacecraft mission. In the meantime, you may want to catch a glimpse of this fleeting celestial object. When you see Mercury shining in the predawn sky, give a thought to the secrets it holds about the origin of the planets. ☐

Clark R. Chapman is a planetary scientist at the Planetary Science Institute in Tucson, Arizona. He is the author of The Inner Planets *and* Worlds of Rock and Ice *and the editor of the forthcoming reference book on Mercury by the University of Arizona Press.*

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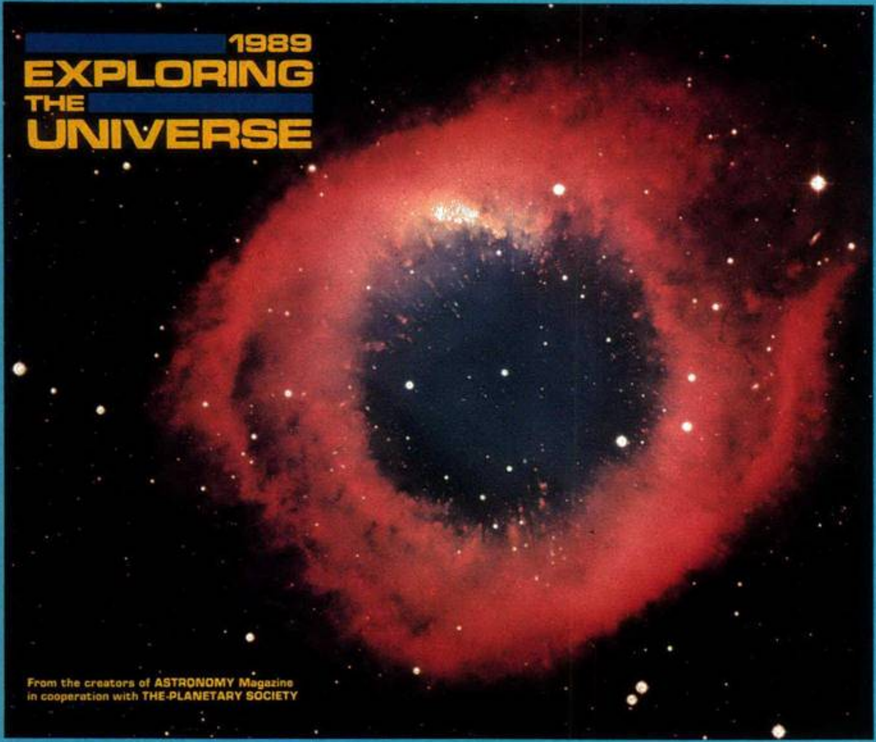
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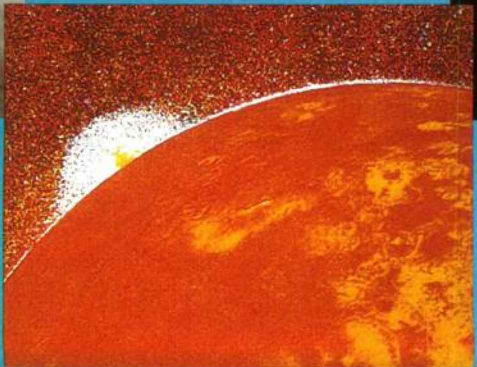

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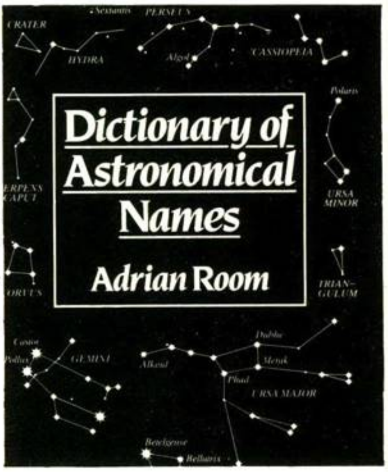

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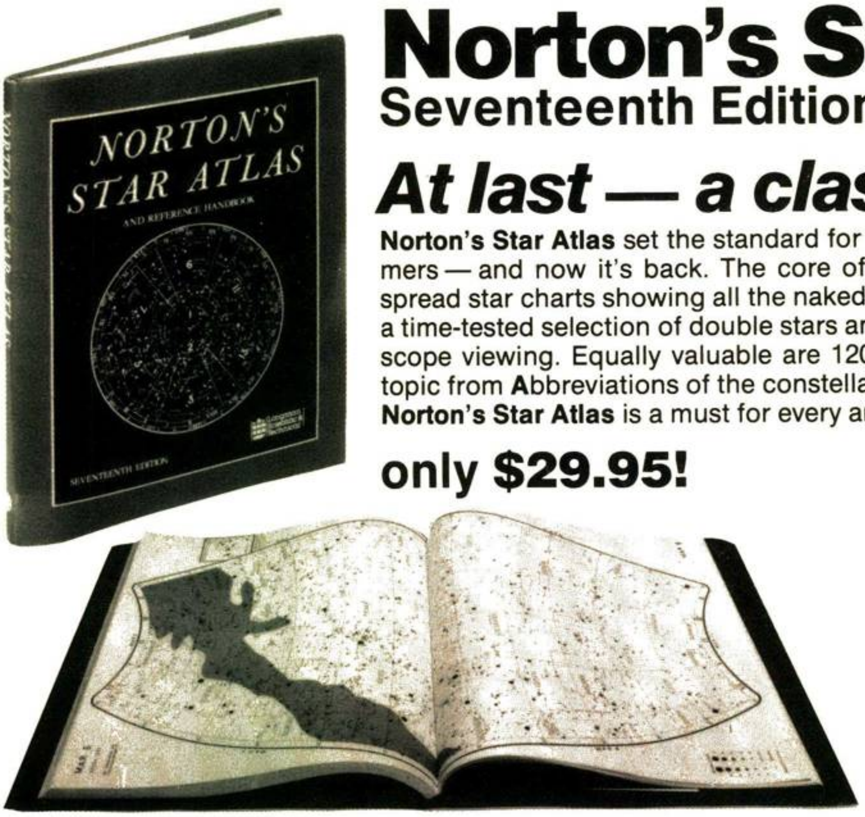

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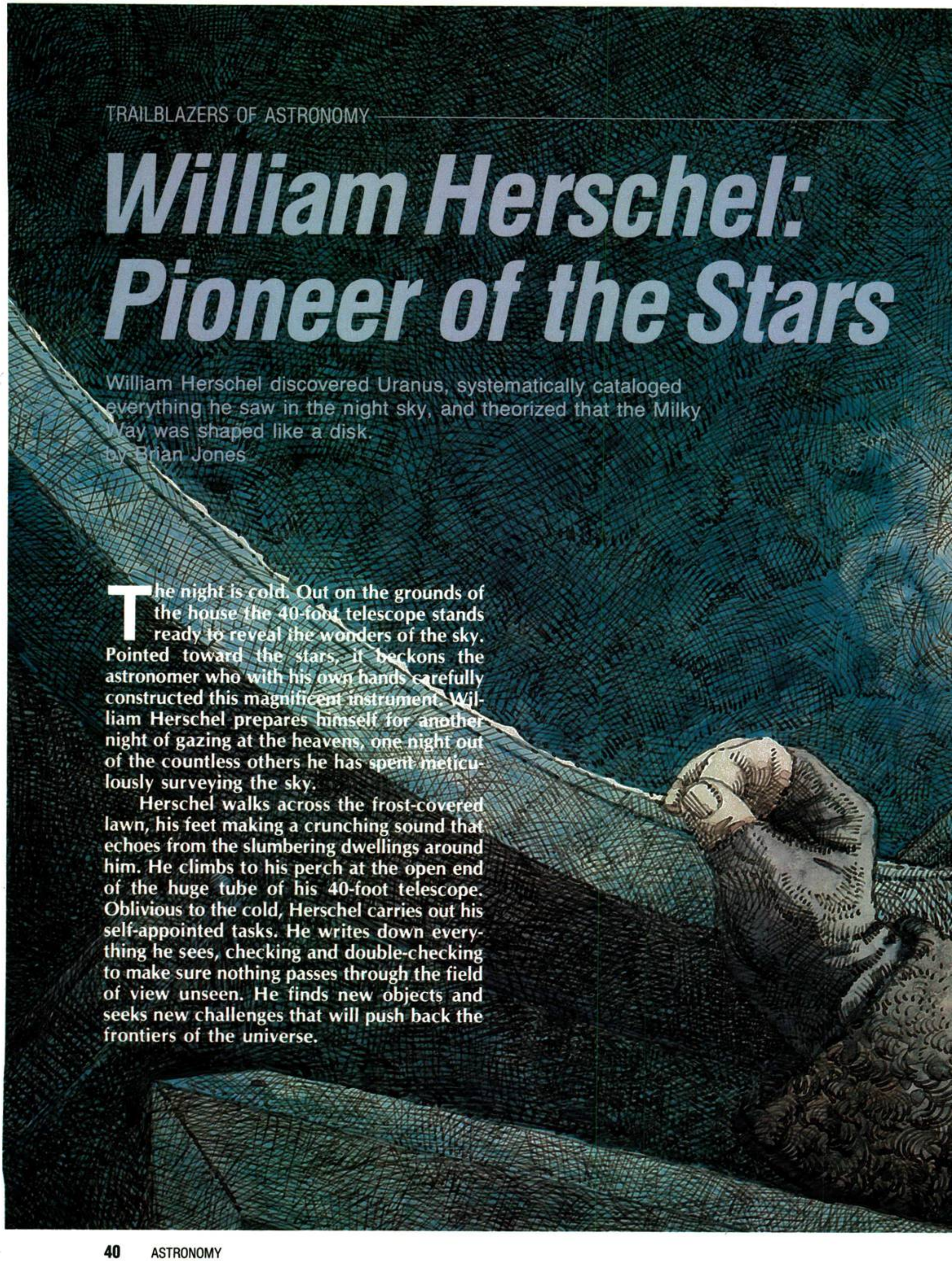
William Herschel: Pioneer of the Stars

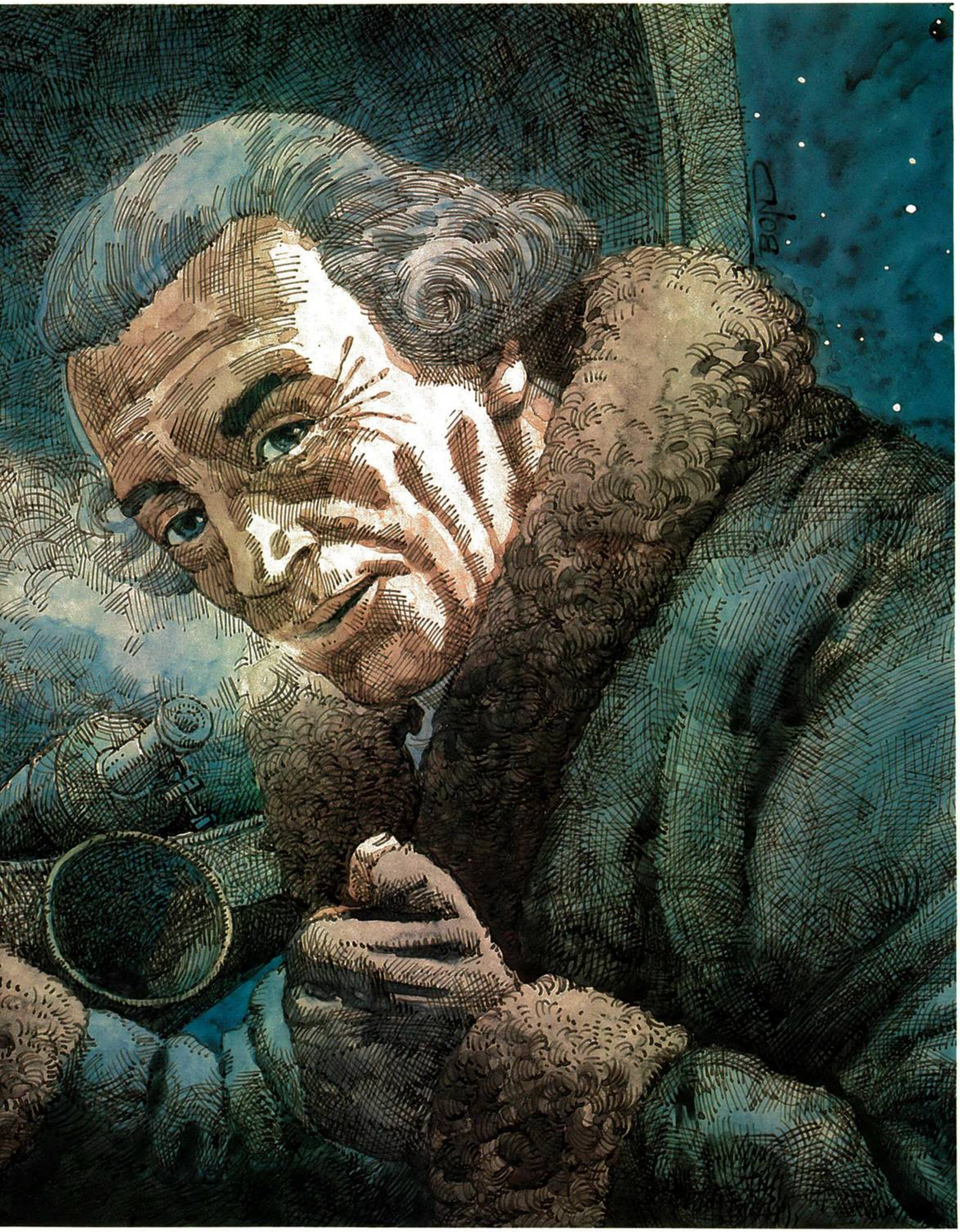
William Herschel discovered Uranus, systematically cataloged everything he saw in the night sky, and theorized that the Milky Way was shaped like a disk.

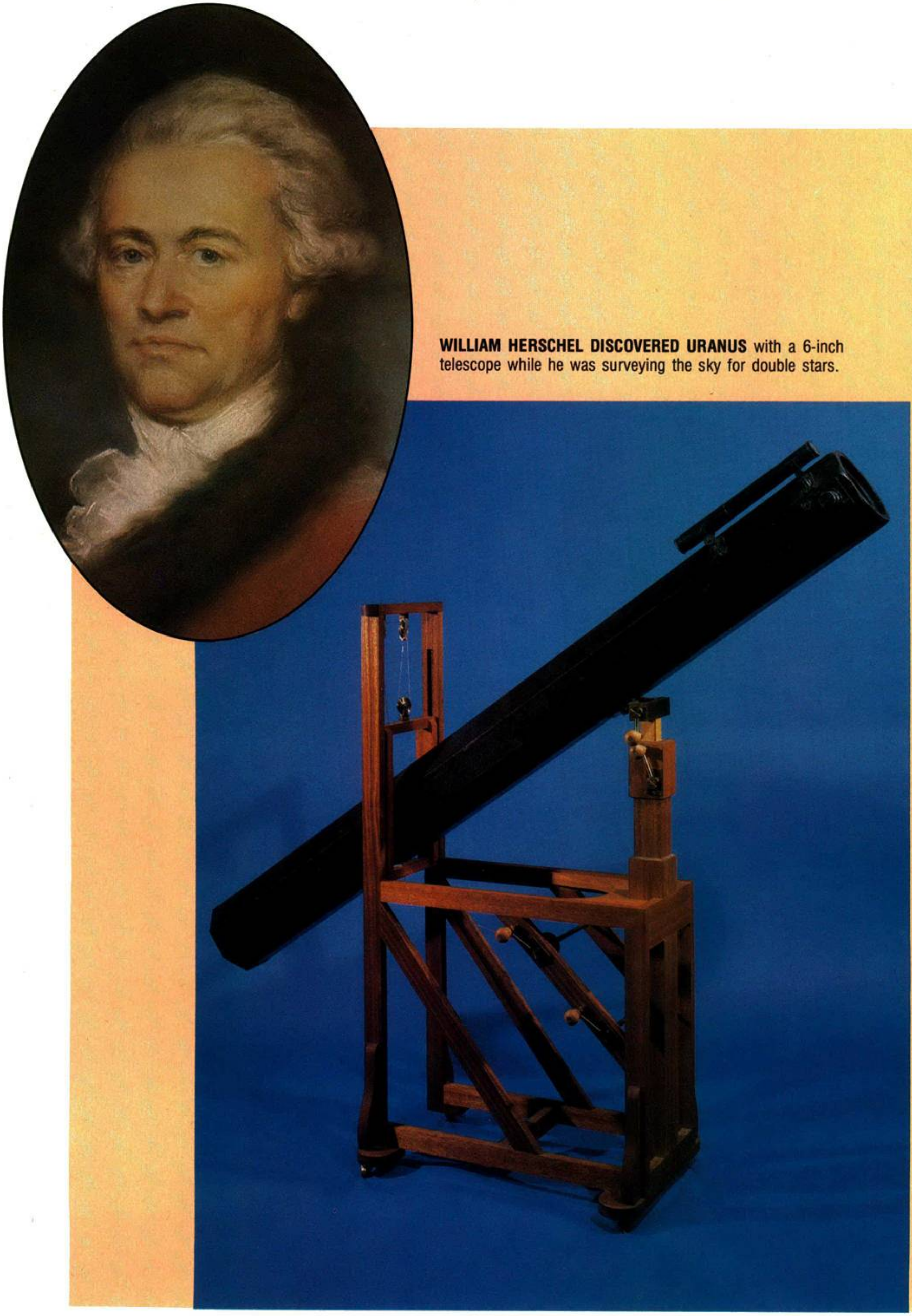
by Brian Jones



The night is cold. Out on the grounds of the house the 40-foot telescope stands ready to reveal the wonders of the sky. Pointed toward the stars, it beckons the astronomer who with his own hands carefully constructed this magnificent instrument. William Herschel prepares himself for another night of gazing at the heavens, one night out of the countless others he has spent meticulously surveying the sky.

Herschel walks across the frost-covered lawn, his feet making a crunching sound that echoes from the slumbering dwellings around him. He climbs to his perch at the open end of the huge tube of his 40-foot telescope. Oblivious to the cold, Herschel carries out his self-appointed tasks. He writes down everything he sees, checking and double-checking to make sure nothing passes through the field of view unseen. He finds new objects and seeks new challenges that will push back the frontiers of the universe.





WILLIAM HERSCHEL DISCOVERED URANUS with a 6-inch telescope while he was surveying the sky for double stars.

CAROLINE HERSCHEL assisted her brother by taking notes and keeping records for him.

William Herschel's research, conducted with the largest and finest telescopes in the world at the time, probed the secrets, not just of the solar system, but of the realms of deep space beyond. He added a third dimension to the universe by attempting to formulate the structure of the Milky Way. So thorough and imaginative was his work that he shattered the old conception that the stars were merely a backdrop against which the objects of the solar system moved.

In the eighteenth century when Herschel started out as an amateur astronomer, professional astronomers concentrated primarily on the solar system. The motions of the planets on our celestial doorstep took precedence over the properties of the distant stars. Because the stars had no detectable motion, astronomers thought that all the stars lay at immense distances.

The study of the stars as objects in their own right was heralded by Herschel. Through his originality, enthusiasm, and devotion, Herschel entered the halls of astronomy and opened up a new way of understanding the universe. After Herschel, the nature and characteristics of the stars demanded the attentions of astronomers, who were forced to acknowledge that the universe stretched far beyond the confines of the solar neighborhood.

Herschel was a musician by profession. He was born in Hanover, Germany, in 1738, the fourth child in a large family, of whom all the members were musical. When Herschel settled in England in 1757, he performed and taught music in much of the country and eventually became the organist at the Octagon Chapel at Bath in 1766.

So what caused him to turn from music to astronomy? From a description given by Herschel, music was linked to harmonics, and Herschel took every opportunity to expand his knowledge of this topic. He was drawn from one branch of mathematics to another until he read *Harmonics* by Robert Smith and then *A Compleat System of Opticks* by the same author. The second book contained a section on descriptive astronomy, and this fired Herschel's enthusiasm. Herschel wanted to observe the heavens himself and, using Smith's book as a guide, he commenced what would become his life's work of studying the stars.

After the age of forty, Herschel devoted almost all of his time to astronomy. Herschel's earliest recorded observations — of a lunar eclipse and of Venus — seem to have been made in February 1766. For more than a decade after this, astronomy was his hobby. In 1774 Herschel wrote in his diary that he was teaching music to as many as eight students a day and surveying the heavens by night; by 1779 he had about half that number of music students. Two or three years later he was regularly being requested to give lessons on astronomy rather than music.

Builder of the Biggest Telescopes

Using the techniques outlined in Smith's book on optics, Herschel constructed his own telescopes — mirrors, tubes, mountings, and all — and attained a high degree of workmanship. He started with refracting telescopes using ready-made lenses, but he soon turned to reflecting telescopes using mirrors made from metal, because the optics for refractors were expensive and the tubes long and unwieldy. It was fairly easy for the dedicated amateur to cast, grind, figure, and polish mirrors.

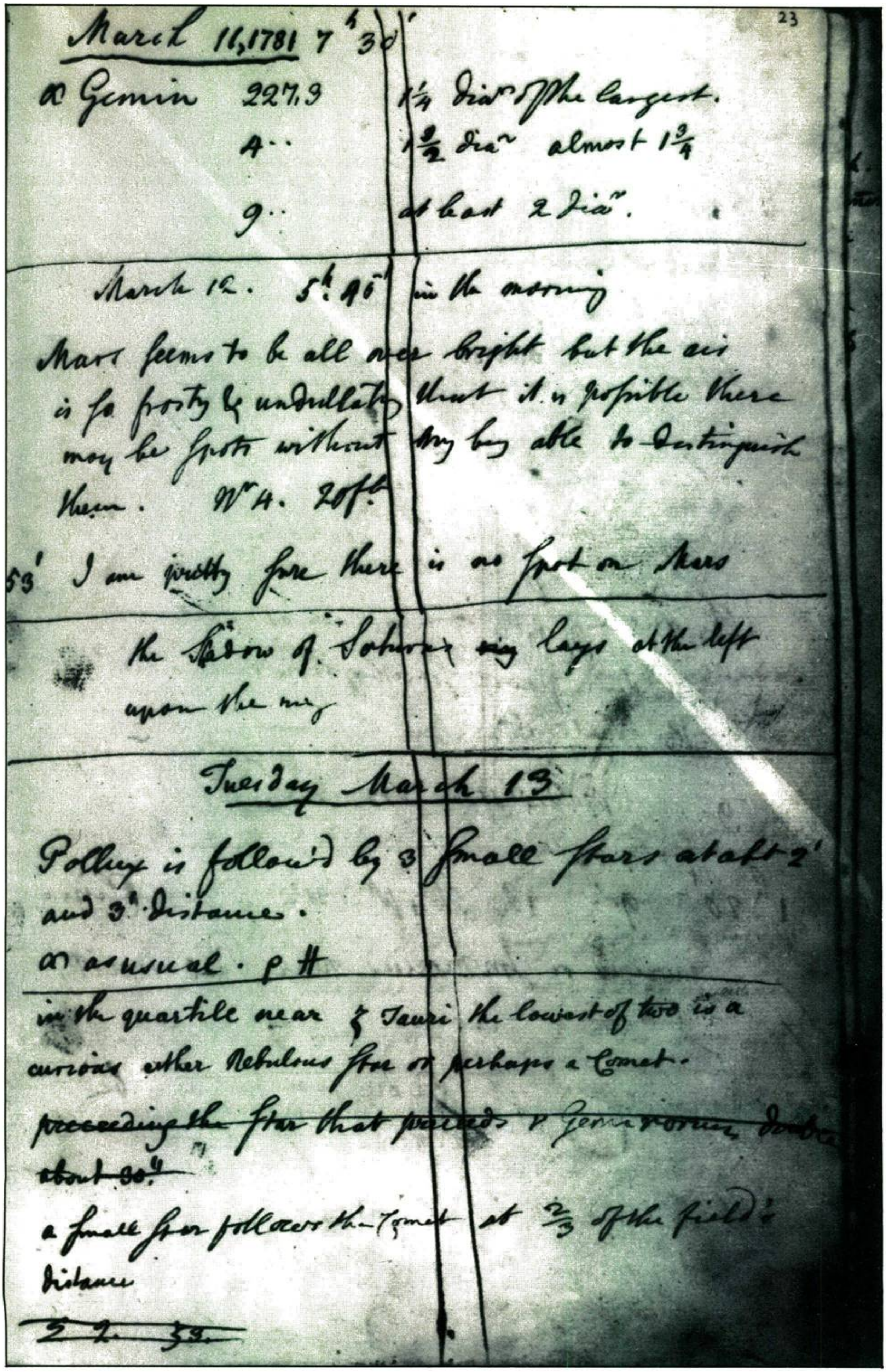
During his lifetime Herschel ground hundreds of mirrors, including many with large diameters. These were not only for himself but for others as well, and the income from the sale of his telescopes was invaluable, particularly in the early years.

He was so obsessed with astronomy that once when he was finishing off a mirror, not having taken his hands away from it for many hours, his sister Caroline had to feed him so he could carry on the work uninterrupted! This was not an isolated incident: Caroline helped her brother in similar ways many times.

A passage from Caroline Herschel's memoirs shows how the Herschel household was turned over almost completely to astronomy and gives us some idea of the Herschels' lifestyle. She wrote: "To my sorrow I saw almost every room turned into a workshop. A cabinet-maker making a tube and stands of all description in a handsomely furnished drawing-room;. . .a huge turning machine. . .in a bedroom, for turning patterns, grinding lenses, and turning eyepieces, etc."

Herschel the Observer

With the telescopes he built, Herschel systematically observed the objects within the solar system and those beyond. One of his favorite solar system objects was Saturn. Herschel discovered two satellites of Saturn — Mimas and Enceladus — in 1789. He suggested that the



March 16,1781 7h 30'

α Gemin 227.3 | 1¼ diar of the largest.
4.. | 1½ diar almost 1¾
9.. | at least 2 diar.

March 12. 5h 40' in the morning

Mars ſeems to be all over bright but the air is ſo frosty & undulating that it is poſsible there may be ſpots without my being able to distinguish them. Nr 4. 20ft.

53' I am pretty ſure there is no ſpot on Mars

the ſhadow of Saturn ~~ring~~ lays at the left upon the ring

Tuesday March 13

Pollux is follow'd by 3 ſmall ſtars at abt 2' and 3' diſtance.
α as usual. p #

in the quartile near ζ Tauri the lowest of two is a curious either Nebulous ſtar or perhaps a Comet.

~~preceding the ſtar that precedes ν Geminorum double about 30".~~

a ſmall ſtar follows the Comet at ⅔ of the field's diſtance

~~5. 7. 33.~~

THE "COMET" near Eta Geminorum, noted in Herschel's March 13, 1781, observing log (opposite page, lower half) turned out to be Uranus. The discovery shocked the astronomical world and doubled the size of the solar system.

atmospheric changes observed on Jupiter were caused by winds. In 1797 he reported that the four Galilean satellites fluctuate in brightness as they revolve around Jupiter.

He was interested in the minor planets in the early 1800s, and he tried to estimate the diameters of Ceres, Pallas, and Juno. This series of observations confirmed that these bodies were very small by planetary standards. He noted that when viewed through the telescope, they appeared as starlike points of light, which led him to propose the term "asteroids," which means "starlike," for this collection of objects.

Herschel also devoted time to the variable star Mira. He observed Mira on a regular basis from 1777 onward and this star was the topic of papers submitted both to the Philosophical Society of Bath in 1781 and to the Royal Society ten years later.

However, though Herschel was interested in objects within the solar system, these observations were merely sidelines to Herschel's main interest — the stars.

With seemingly boundless energy, Herschel set about surveying the entire night sky visible from England. He used a method of observation known as "sweeping." Bit by bit he examined the entire sky as it passed though the field of view of his telescope. During sweeps he noted everything he saw, including whether a star was double or multiple, whether it was nebulous or showed color. He also noted variable stars and found changes in brightness during later observations of the same areas.

Sweeping the entire sky was tedious and time-consuming. With his sister Caroline, who was his assistant, he turned night into day in the household, surveying the sky every clear night. What sleep they did get was snatched during hours of daylight or when the sky became cloudy. He was also busy constructing telescopes by day and doing a few nonastronomical things like attending concerts in the evenings.

In all, Herschel carried out four "surveys of the heavens." Each survey revealed more than the previous one and he discovered and cataloged thousands of nebulae and hundreds of double stars. In August 1779 Herschel began the second of these surveys to detect double stars to be used for distance estimates. He used what he referred to as a most capital telescope, which he had completed in 1778. It had a 6.2-inch mirror and a focal length of 7 feet. The search took two years and resulted in his first catalog of over 250 double stars.

The Discovery of Uranus

During this survey Herschel became famous, but not for double stars. On the evening of March 13, 1781, Herschel came across a distinctly nonstellar object near the star Eta Geminorum. He noticed that it appeared larger than the neighboring stars and suspected that it was a comet. It wasn't long before the new object was observed by other astronomers, and the computations made of its passage through the sky revealed that it was traveling in a near-circular orbit at a distance roughly twice that of Saturn.

Herschel had discovered a new planet, which shocked the astronomical world. Prior to the discovery, only the five planets discovered in antiquity — Mercury, Venus, Mars, Jupiter, and Saturn — were known to astronomers. The discovery of Uranus, as the new planet came to be named, doubled the size of the solar system. Galileo had discovered satellites of Jupiter, but a new major planet was sensational news indeed.

The Court Astronomer

Well-placed friends pushed Herschel's interests to the King, and fourteen months after the discovery of Uranus King George III requested Herschel's attendance at court. Herschel packed up numerous star charts, catalogs, and the 7-foot telescope and set off to London. King George was so impressed with Herschel and his telescope that he appointed Herschel Court Astronomer.

Herschel was granted a pension from the King so he could carry on his astronomical interests full-time. Herschel went back to Bath, collected his belongings, and the Herschel household moved to a house in Datchet near Windsor Castle. Within two days of his arrival Herschel was once more carrying out observations of double stars.

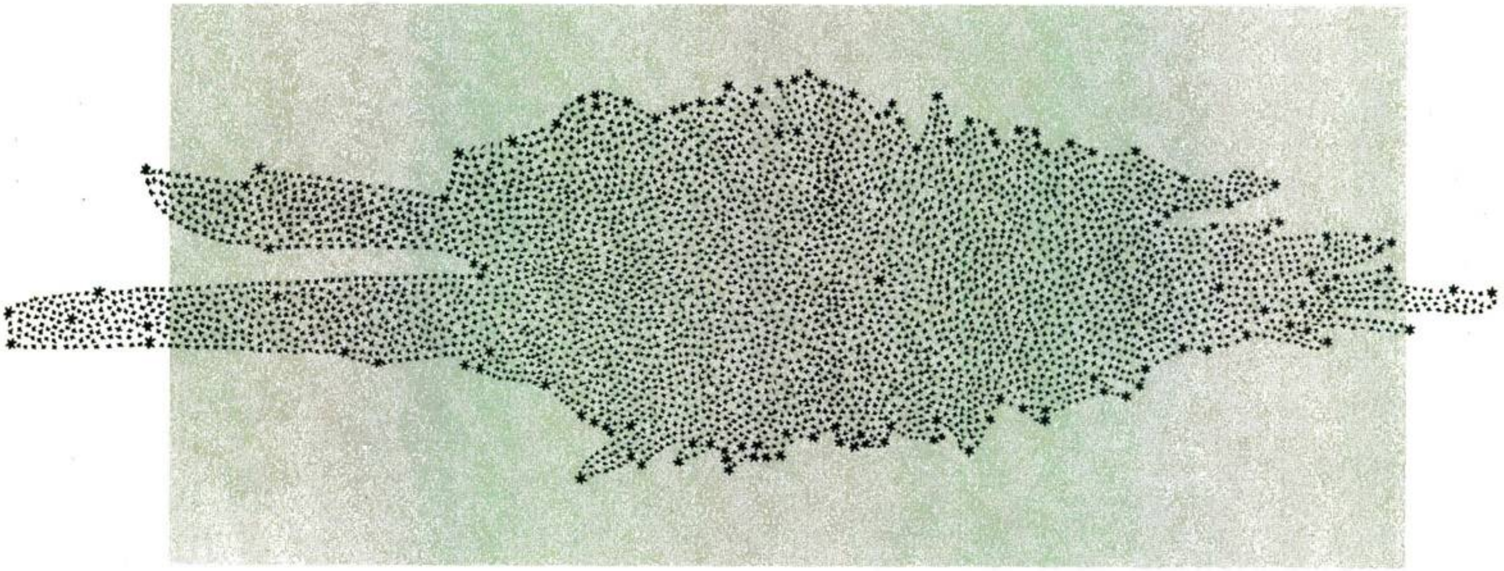
The release from his musical duties was a tremendous boost for Herschel. "I employed myself now so entirely in astronomical observations, as not to miss a single hour of star-light weather, for which I used either to watch myself or keep up somebody to watch; and my leisure hours in the daytime were spent in preparing and improving telescopes."

From now on he was able to devote all his time to the subject that he loved best — astronomy. The king had bestowed on him a salary of 200 British pounds per year, which, together with the revenue from making telescopes, enabled him to scratch out a living. He wasn't entirely happy, however. To make ends meet, he had to devote time to making telescopes (including some for the king), although he badly wanted to use this precious time observing the sky. Still, things weren't too bad for Herschel. The pension he received compared well to the 300 British pounds salary paid to the Astronomer Royal at the time.

The house into which Herschel and his sister Caroline moved was in a state of disrepair, although Herschel turned a blind eye to this. What pleased him were the stables that were to become a workshop for grinding telescope mirrors and a laundry that would be converted into a library. There was also plenty of room in the gardens for the telescopes.

After the move to Datchet, Caroline began sweeping for comets; she would discover eight comets in the next two decades. Her brother began to demand more and more of her time to assist him in his observations, however, and she was forced to temporarily abandon her comet sweeps. She wrote: "I became entirely attached to the writing desk." As if this wasn't enough, she was also called upon to "run the clocks, write down a memorandum, fetch and carry instruments." Caroline was essential to her brother's work.

Herschel's third survey of the sky was completed by early 1784 and resulted in the second *Catalogue of Double Stars,* which contained details for over four hundred objects. This was presented to the Royal Society later that year. During this survey Herschel worked under tremendous pressure, and he often made observations for up to twelve hours at a stretch. The only respite he got was during nights that were either cloudy or



OUR SIDEREAL SYSTEM, as Herschel called the Milky Way, had a definite size and shape, although the exact dimensions couldn't be determined because no one knew the distances to the stars. Herschel counted the stars visible with his 20-foot telescope (opposite page) to determine the relative density of the stars. The Sun lies just right of center.

moonlit.

What made matters worse was that he carried out his work in the open air, because he thought that ideally the telescope should be the same temperature as its surroundings. His keenness to observe regardless of such considerations as freezing temperatures astounded those around him, including the famous German astronomer Baron von Zach, who paid Herschel a visit in January 1784.

Von Zach summed up Herschel's enthusiasm for observing the sky: "The thermometer. . .stood at 13°F; but in spite of this, Herschel observes the whole night through. . . .For some years Herschel has observed the heavens every hour when the weather is clear. . . .He has an excellent constitution and thinks nothing else in the world but the celestial bodies."

Herschel observed many other objects during his stay at Datchet, including the variable star Mira, the Moon, and the planets, especially Mars. However, these are overshadowed by the series of observations that offered proof that the Sun and planets were moving together through space. In the paper entitled "On the Proper Motion of the Sun and Solar System," presented to the Royal Society in 1783, Herschel tackled the problem of working out the details of the Sun's motion.

The Motion of the Sun

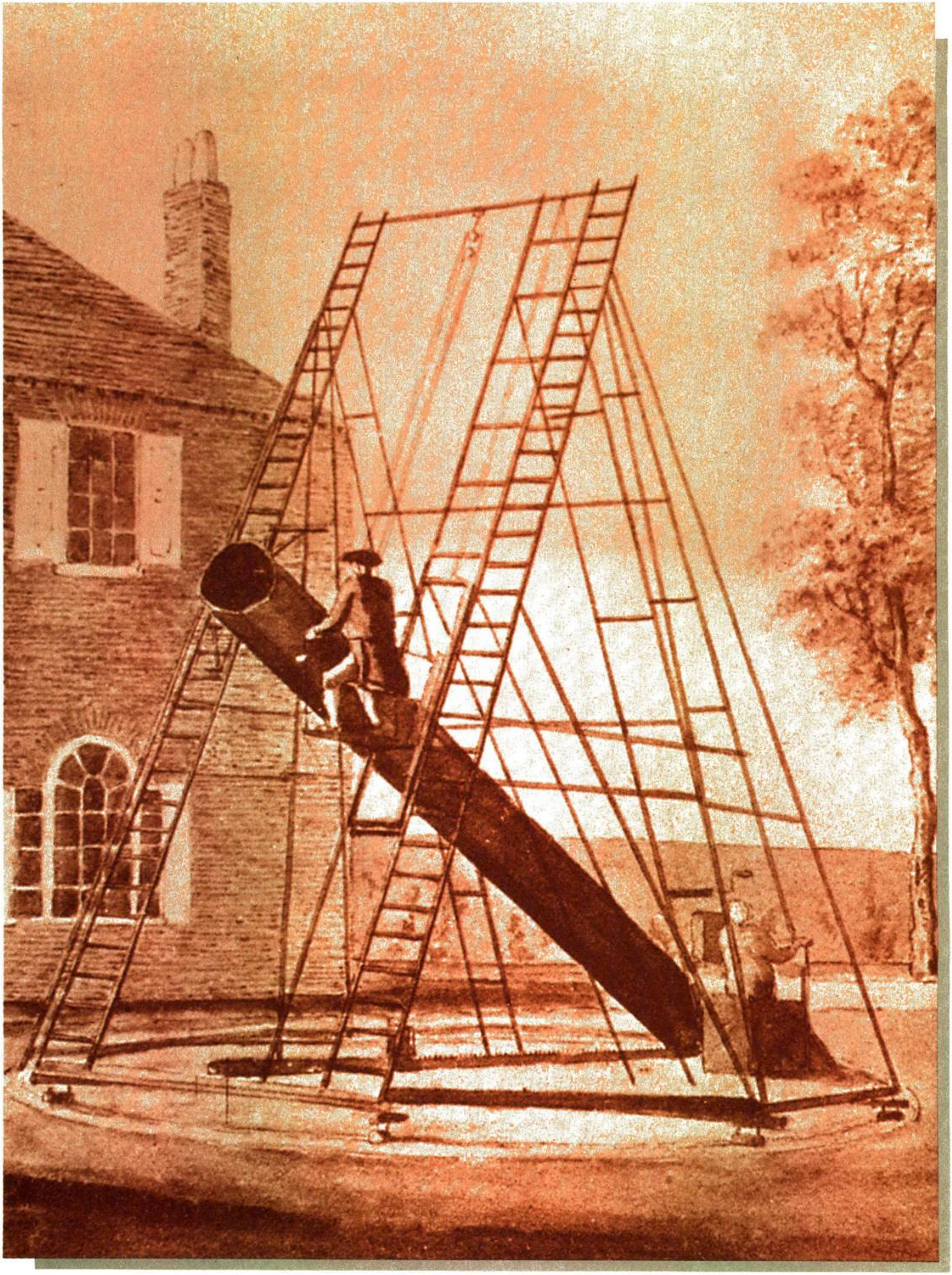
A number of stars had already been shown to have moved through space, and Herschel believed that the Sun also had such motion. He reasoned that the motion of a star through space as seen from Earth is made up of two factors: the star's actual motion and the star's apparent motion, which is caused by the Sun's motion.

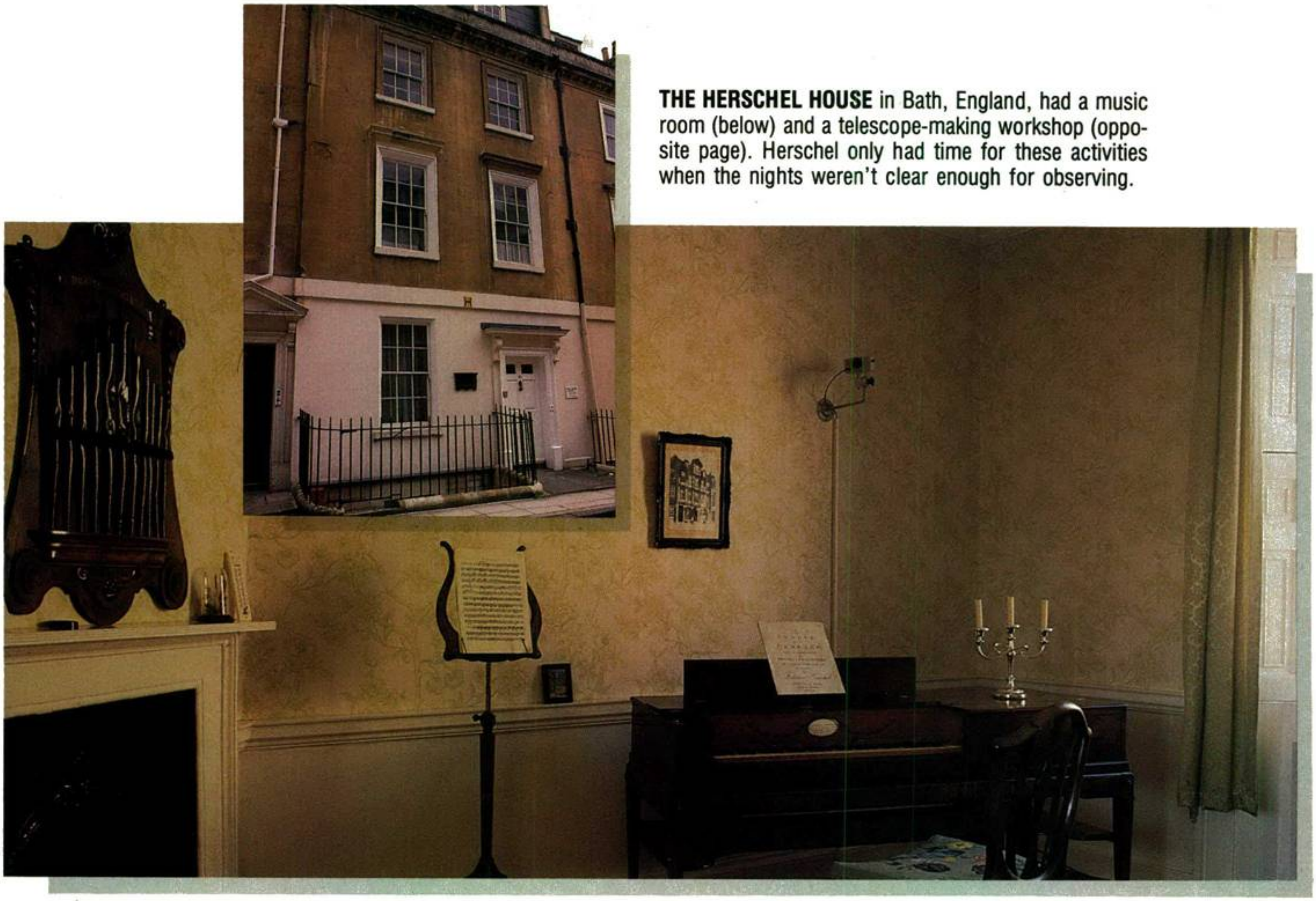
Had all the other stars in the sky been stationary, any observed motion would have been the direct result of the Sun's motion through space. The stars toward which the Sun was traveling would appear to diverge, or open out, while those from which the Sun was receding would appear to converge, or close up.

However, because the other stars in the sky possessed motions of their own, it would have been difficult to separate the true motion of the star from the star's apparent motion. The only way to determine the direction of the Sun's movement would be to observe a great number of stars to see if their motions averaged out, which would produce a shift common to each of them and thereby indicate the Sun's direction of travel.

Herschel used values derived by other astronomers, including the Astronomer Royal at that time, Nevil Maskelyne, and the French observer J. J. F. Lalande. He deduced that the observations were best explained by assuming that the Sun was traveling toward a point in the constellation Hercules. These findings were supported by an examination of the proper motions of more than forty stars compiled by the Gottingen astronomer Tobias Mayer. One or two stars were found to have motions that did not correspond to the rest; these were assumed to belong to another star system traveling in a different direction.

Herschel's conclusions were at first received with a great deal of speculation by the astronomical community, although later investigations into the problem — based upon the proper motions of many more stars — have generally confirmed Herschel's findings.





THE HERSCHEL HOUSE in Bath, England, had a music room (below) and a telescope-making workshop (opposite page). Herschel only had time for these activities when the nights weren't clear enough for observing.

The 20-foot Telescope

Shortly after settling at Datchet, Herschel began work on his 20-foot telescope, which had an aperture of just over 18½ inches. This telescope was in use well before the end of 1783. Herschel used this instrument more than any other in the following decades and carried out all his sweeps for nebulae with it up to 1802. Herschel was so eager to use this telescope that he started observing with it before it was completed! Caroline had many misgivings during this period because he balanced on temporary cross-structures when observing rather than the unfinished observer's gallery. At one time shortly after he had finished an observing run, the whole telescope came crashing down.

Herschel continued his relentless observations at Datchet, though the location of the house left much to be desired. At times the waters from the nearby Thames river lapped at the foot of the garden.

Herschel wrote of the conditions under which he worked: "The tube of my 7-foot telescope is covered with ice; yet I see very well. . .more than once have I found my feet fastened to the ground, when I have looked long at the same star. . .Datchet Common, which is just beyond my garden, is all under water; and the grass on which I stand with my telescope is as wet as possible. . .All the ground is covered with snow."

As a protection against the cold, Herschel rubbed his hands and face with raw onion. Yet in spite of this precaution and his robust constitution, Herschel fell seriously ill with ague in early 1785. After he recovered, the Herschels moved to a much healthier and drier location at Windsor.

Before leaving Datchet, however, Herschel carried out a review of the entire sky in search of nebulae and star clusters with the idea of adding to the list that had been compiled by the French astronomer Charles Messier and printed in 1784. Messier's list contained 103 nebulous objects that had caused him confusion during his searches for comets and was the first catalog of its kind. Herschel's compilation, presented to the Royal Society in 1786, was his first *Catalogue of One Thousand New Nebulae and Clusters of Stars.*

The Construction of the Heavens

His work cataloging nebulae and star clusters highlighted the fact that these objects were abundant in certain areas of the sky and absent in others, and Herschel began to view the stars as an organized system in space with definite shapes and a finite size. In 1784 he submitted his first major paper to the Royal Society on the construction of the Galaxy.

He noted that it was "very probable that the great stratum, called the Milky Way, is that in which the Sun is placed, though perhaps not in the very centre of its thickness. We gather this from the appearance of the Galaxy, which seems to encompass the whole heavens, as it certainly must do if the Sun is within the same." This paper's premise differed greatly from the contemporary idea that the stars were only lights on a celestial sphere.

What Herschel was pondering was, of course, the form of we now call the Milky Way Galaxy. His main problem was that he didn't know the distances of the stars. For all intents and purposes the stars appeared to be points of light at equal distances, so to derive the

dimensions of his stellar universe (the Milky Way), he had somehow to estimate the distances of the stars on its boundary.

As far as the shape of the star system was concerned, Herschel had a couple of possible suggestions based on the fact that the Milky Way extended completely around the sphere of stars, cutting the sky almost into two halves. This band of light, which the telescope resolved into countless stars, was not uniform throughout its length but subject to irregularities in width and brightness. Broadly speaking, the appearance of the Milky Way could be explained if the star system (as Herschel called the Milky Way) were either doughnut-shaped, surrounding a more barren region within which the Sun is located, or a huge, circular, disklike structure. Herschel adopted the latter explanation and surmised that the Sun would be located somewhere inside the disk and that the Milky Way would be the effect of looking along the main plane of the system.

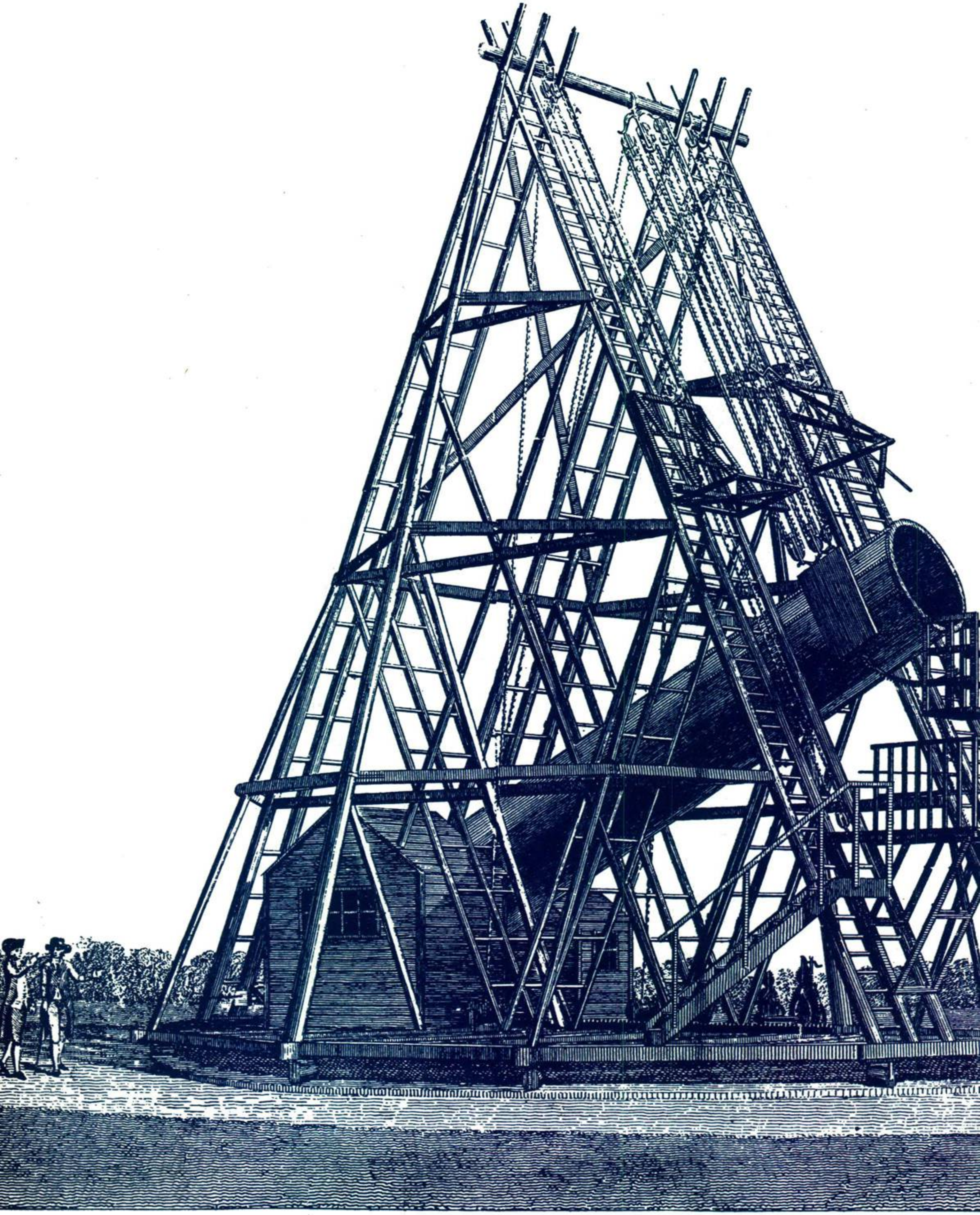
Although Herschel was more or less correct in his assumption about the general shape of the star system, assessing the actual size of the disk of stars was more of a problem. Estimates of the distance to the boundary of the disk in various directions needed to be made to work out just where the Sun was situated. To do this, Herschel assumed that the stars were fairly evenly scattered throughout space and that he was able to see right to the edge of the star system (the rim of the disk).

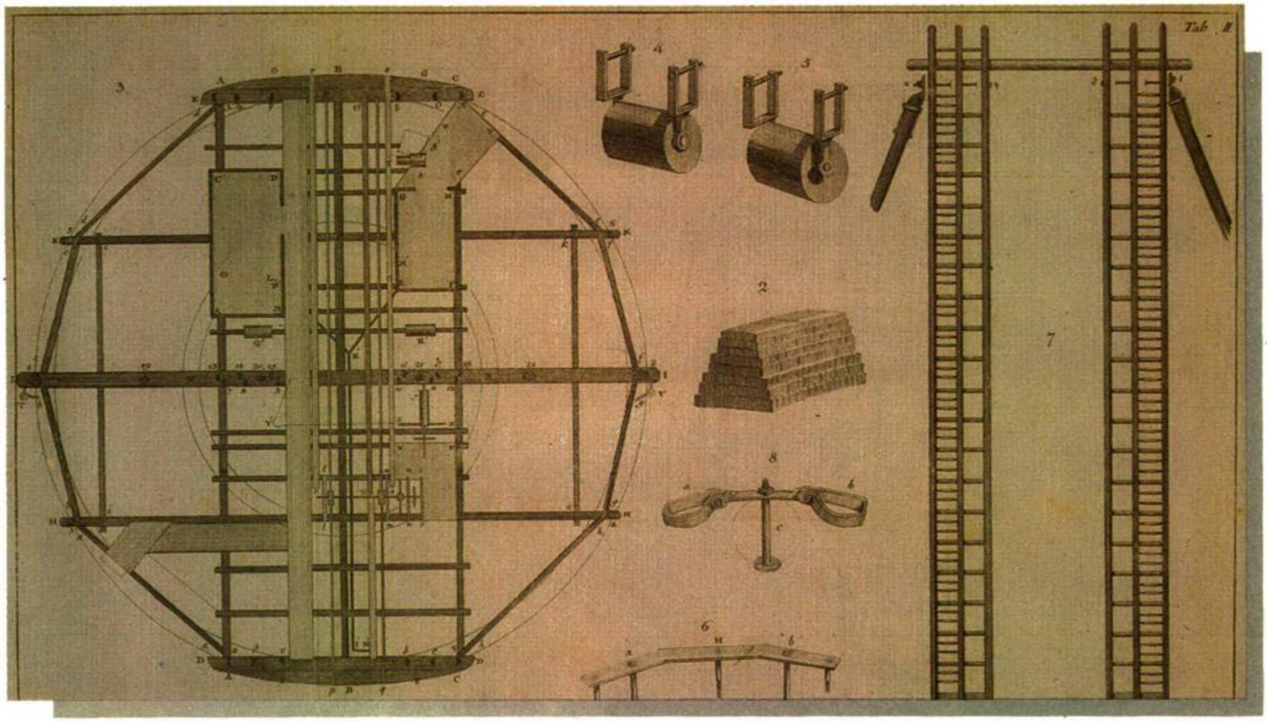
We now know that the Milky Way effect is actually caused by a physical crowding of stars and that Herschel was not entirely correct in his first assumption. We also now know that Herschel was unable to see completely to the boundary of the star system (our Galaxy) in all directions. The central and outer boundaries of the system were not visible because boundless numbers of stars and interstellar material intervened, although Herschel was able to see out to the edge of the system (the Milky Way) in the direction of the galactic poles.

Herschel carried out star counts by aiming his telescope in various directions and counting the number of stars visible in the field of view. He reasoned that the number of stars in a particular field would indicate the thickness of the star system in that direction. Taking this farther, the thicker the field with stars, the farther the boundary of the star system extended in that direction.

The results he obtained from the fields showed that there were very few stars in the field when looking away from the plane of the Milky Way, whereas there were quite often several hundred stars when looking along the plane of the Galaxy. Of course, this is the result we would expect. Herschel called this observing system "gauging," and the results of his work were eventually published in a second paper on the construction of the heavens, which was presented to the Royal Society in 1785.

This paper established that the star system of which the Sun is a member was disk-shaped or lens-shaped and that the system was, according to Herschel, of a diameter just over four times its central thickness. The gauging he carried out revealed the relative dimensions of the star system, although the true dimensions of the system remained a mystery because no actual stellar distances were known. The idea of a finite-sized star system had been suggested before Herschel's time by the English

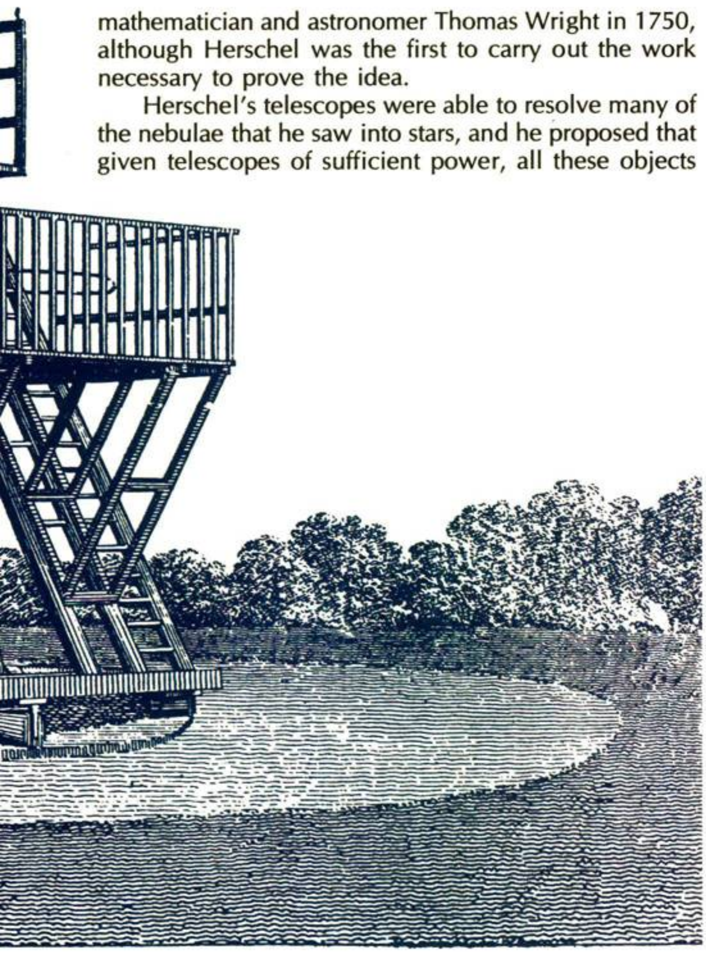




THE 40-FOOT TELESCOPE DREW VISITORS who could only marvel at the size and elaborate system of ladders and pulleys required to operate the instrument. The telescope was aimed vertically by adjusting ropes and horizontally by rotating the entire structure. The tube was moved from side to side by means of a pivot.

mathematician and astronomer Thomas Wright in 1750, although Herschel was the first to carry out the work necessary to prove the idea.

Herschel's telescopes were able to resolve many of the nebulae that he saw into stars, and he proposed that given telescopes of sufficient power, all these objects would be revealed as stellar systems. His theory was that these star clusters would be the natural result of gravity throughout a universe that was originally composed of stars distributed uniformly.

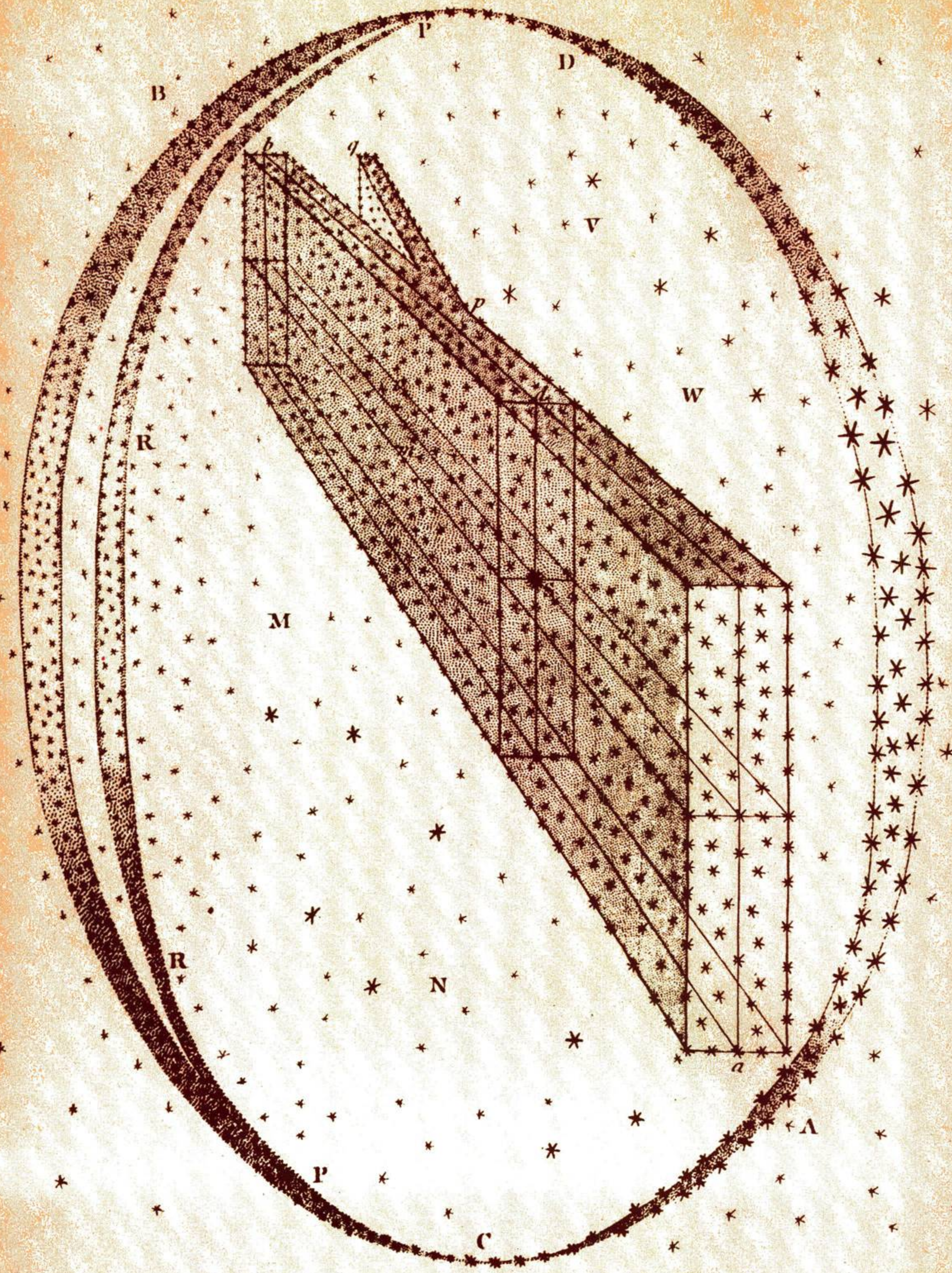


Herschel asked himself whether our own star system was not just one of many that existed throughout the universe. He had been responsible for the discovery of, as he noted in a letter written in 1785 to his friend Fanny Burney, "fifteen hundred whole sidereal systems, some of which might well outview our Milky Way in grandeur." In the preface to his first catalog of nebulae he postulated that "To the inhabitants of the nebulae of the present catalogue, our sidereal system must appear either as a small nebulous patch; an extended streak of milky light; a very compressed cluster of minute stars hardly discernible; or as an immense collection of large scattered stars of various sizes. And either of these appearances will take place with them according as their own situation is more or less remote from ours." As it turned out, many (although not all) of the nebulae were actually star systems in their own right, although this wasn't proved conclusively until the early part of the twentieth century.

The 40-Foot Telescope

Before the Herschels moved from Datchet to Windsor, Herschel had already begun to plan a much larger and more powerful telescope. Although the garden at Datchet was not large enough to accommodate the proposed instrument, the garden at the Windsor house was. This was no doubt as important a reason for the move as the location of the previous house.

Herschel had long wanted something better than the 20-foot telescope, although he knew that building a new telescope would be a costly affair. The king heard about Herschel's financial plight and his need for improved instrumentation, and he granted Herschel 2,000 British pounds to pay for the labor of constructing the telescope, the mounting, and so on. Herschel was to make the optics himself. The size fixed upon was a 40-foot telescope, although before it was completed, a further grant of 2,000 pounds was made, together with an annual allowance of 200 pounds to pay for its maintenance.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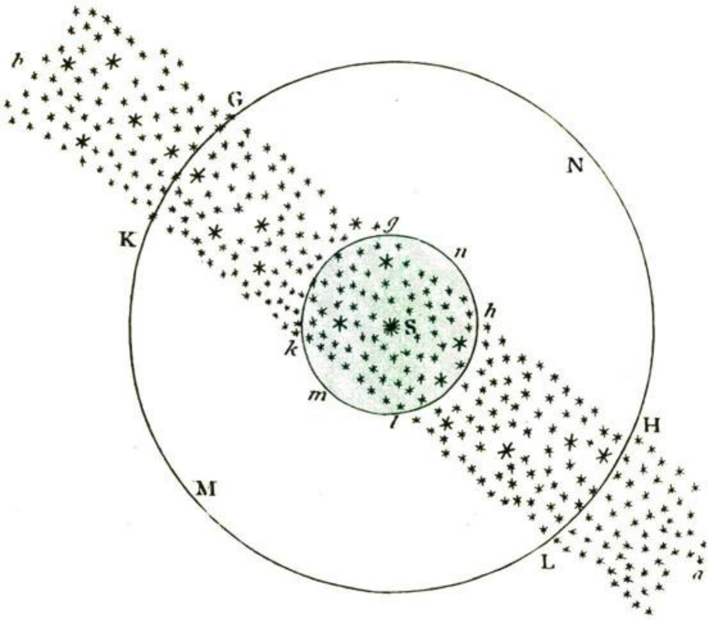

FROM THE HEART OF A BOX-SHAPED LAYER of stars the Milky Way would look like a ring of stars (opposite page), according to Herschel. "The starry stratum" is cleft at one end, not too far from the Sun's position in the Galaxy, to account for the observed division of the Milky Way into two branches in Cygnus and Scutum. Herschel also noted that the number of stars visible would be different depending on the instrument used. The smaller circle (above) corresponds to the starry stratum visible with a small instrument; the larger circle shows the portion visible with a large telescope.

Caroline was also allocated an annual salary of 50 pounds for her work as Herschel's assistant.

The construction of the telescope required the efforts of a large gang of workmen. Herschel carefully planned every aspect of the new telescope, paying particular attention to the construction of the 48-inch diameter mirror. During the first few months of the project the Herschels moved for the last time, this time to Slough. The owner of the house at Windsor had demanded more rent because the new telescope would increase the value of the property. Herschel would have none of this and decided to leave the house. The move took place in April 1786 and, as was typical, not a night's work was lost. The telescope that was used on the last night before the removal stood ready for action on the first evening at Slough.

Shortly after the move to Slough, Herschel made a journey to Germany to oversee the delivery of one of his telescopes to Gottingen University and visit his family. Caroline was left back at Slough to supervise the workmen, which she called a "swarm of pilfering work people." She also spent time reducing observations made by her brother and continuing her sweeps for comets. On August 1, 1786, she saw an object in the telescope that proved to be a comet. The discovery was soon confirmed and provided deserved recognition for Caroline.

After four years of hard work the 40-foot telescope was completed, and it became an object of wonder to all who saw it. Many visitors came to the Herschel home to see this marvelous instrument of observation, though Herschel never let the publicity interfere with his observations. Although he had been popular since his discovery of Uranus, the 40-foot telescope created a renewed and much greater interest on the part of the public and other astronomers.

The 40-foot telescope was never used for sweeping the sky; the 20-foot instrument was employed for this purpose. It also seems that the 40-foot telescope wasn't used as often as it might have been, and from around 1813 onward it went into disuse and was dismantled in 1839, seventeen years after Herschel's death.

There were several reasons Herschel did not use the 40-foot as often as he might. One was that the mounting, similar to that of the 20-foot, was not efficient enough. The weight of the new telescope demanded a better mounting. Also, two workmen were required for the new telescope rather than the single workman needed to help operate the 20-foot. The smaller telescope could also be made ready for use far quicker than the 40-foot, which gave Herschel more observing time.

Marriage and Later Life

While he was living at Slough, Herschel married Mary Pitt. The marriage took place in May 1788 and proved to be traumatic for Caroline. Throughout the past few decades Herschel and Caroline had enjoyed a close relationship, both as family and as astronomers. After Herschel's marriage she was suddenly thrust out on her own, no longer her brother's closest family member. However, Mary was a kind-hearted woman who eventually persuaded Caroline that she was as welcome as she had ever been. In the fourth year of marriage a son was born to William and Mary Herschel. This was John Herschel, a man destined to become a first-class astronomer and carry on the work and traditions set by his illustrious father.

Even after he married, Herschel's routine didn't change much and his love of observing the heavens remained as strong as ever. Given what we know about Herschel's hectic schedules and his dedication to observing, Mary must have been very patient and understanding.

During the last few years of Herschel's life he became ill and less able to carry out his observations. John assisted his father with various things, including the manufacture of telescope mirrors. The last instrument that William Herschel worked on was a 20-foot telescope that eventually ended up at the Cape of Good Hope with John. Herschel died on August 25, 1822, at the age of eighty-four at his home in Slough.

William Herschel revolutionized the way astronomers observed the sky. Not only did he observe and catalog everything he saw through the biggest telescopes of the time, he also sought to explain what he observed. His theories and discoveries were based on meticulously careful observations, and through these observations he doubled the size of the known solar system and recognized that the stars were organized in a system called the Milky Way. Herschel's grave bears the inscription: "He broke through the barriers of the heavens." A fitting tribute to the amateur astronomer who came to be known as the father of sidereal astronomy. ☐

Brian Jones is an astronomy and spaceflight writer and broadcaster who lives in Bradford, England.

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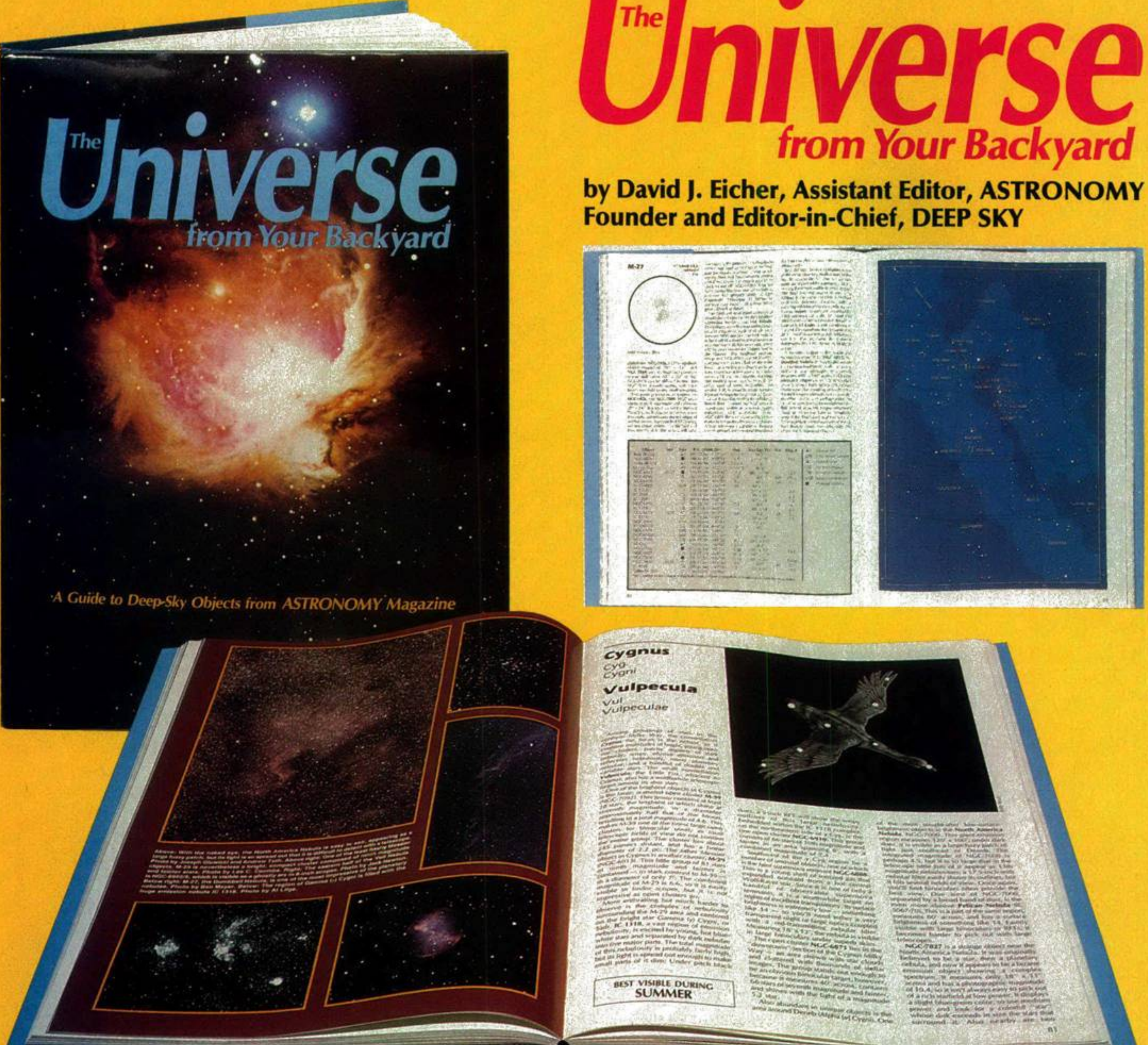
The Universe from Your Backyard

by David J. Eicher, Assistant Editor, ASTRONOMY
Founder and Editor-in-Chief, DEEP SKY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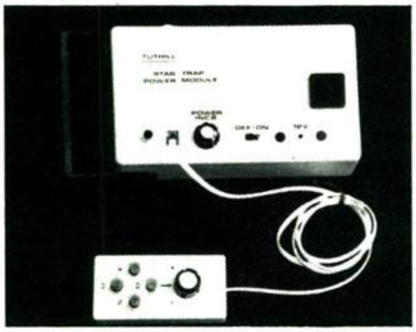

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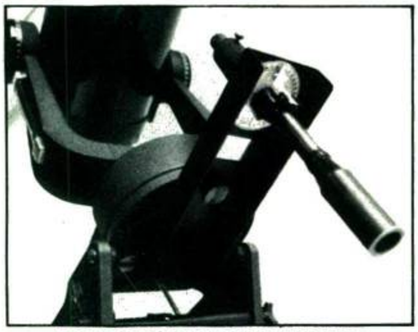

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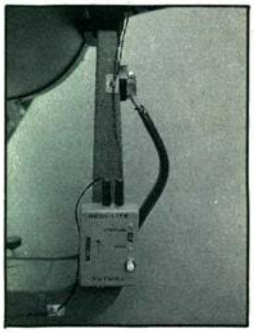

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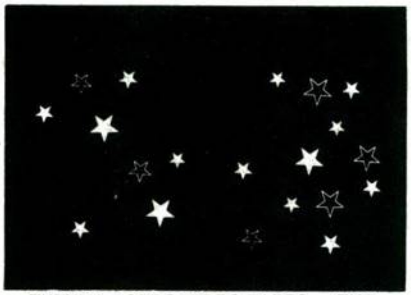

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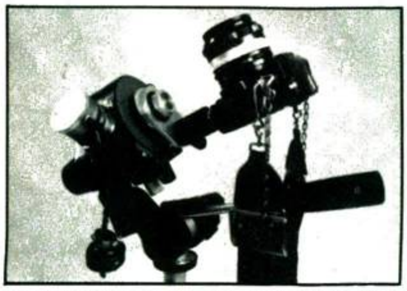

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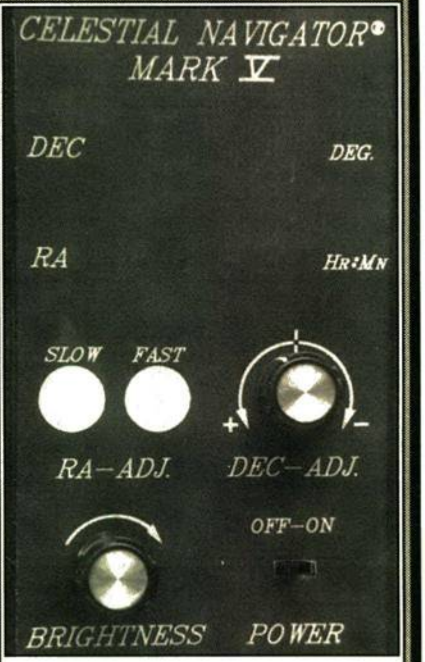

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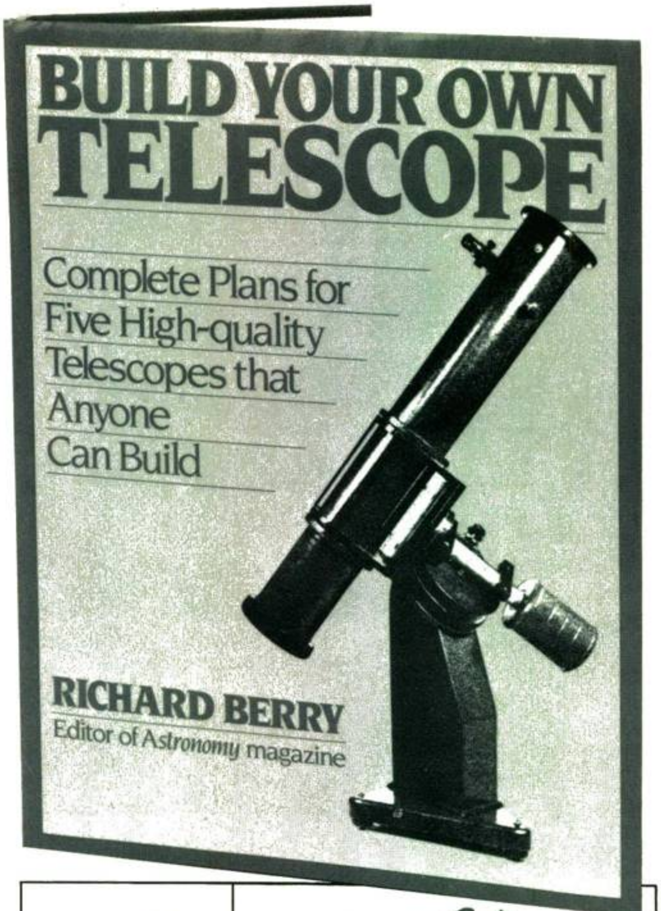

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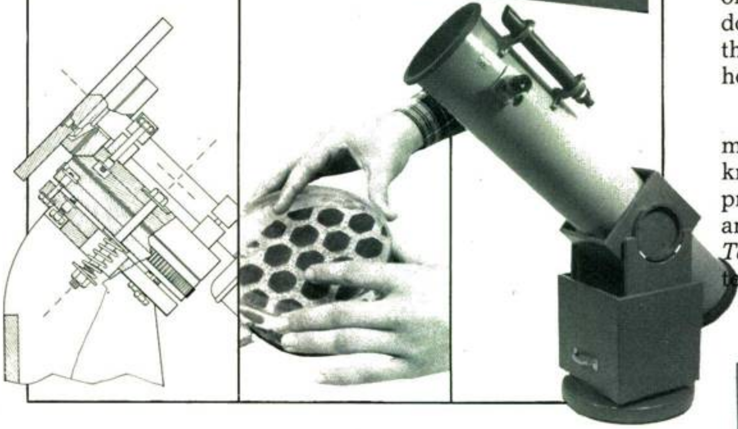

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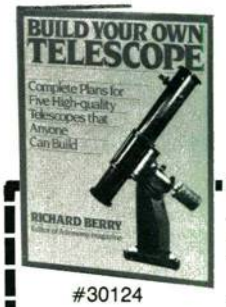

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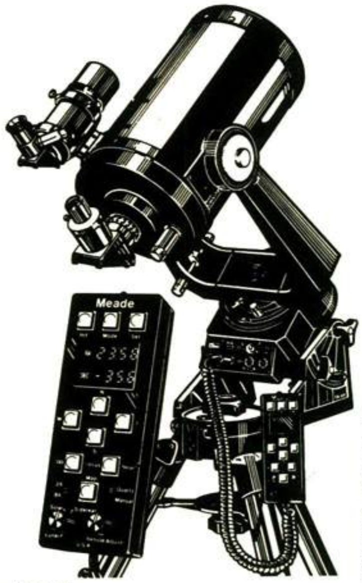

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A New 'Yardstick' for the Universe

With the discovery of a gravity ring, astronomers have found a new way to measure the size of the universe.

by Gerrit L. Verschuur

A unique object discovered by radio astronomers promises to provide clues to important questions about the universe. The object, designated MG1131+0456, is a ring-shaped cosmic mirage produced by a gravitational lens. Astronomer Jacqueline N. Hewitt of the Haystack Observatory discovered the object last spring while studying images made with the Very Large Array radio telescope in New Mexico.

Once astronomers have fully analyzed the ring, MG1131+0456 could yield insights into the amount of dark matter in the universe, the distance scale of the universe, and whether the universe will ultimately collapse or continue to expand forever.

"This ring system is rather special," says Edward L. Turner of Princeton University, a colleague of Hewitt's. Turner is excited because the ring is the first example of a phenomenon predicted by Albert Einstein fifty years ago.

In 1936 Einstein theorized that if a distant galaxy lies directly behind a massive galaxy closer to home, the light from the distant galaxy should be bent and refocused by the interloper, which acts as a giant lens. And if the galaxies are exactly aligned, the lens galaxy would produce an illusionary image of the distant galaxy that resembles a ring.

A gravitational lens acts differently than the glass lens in a telescope. Gravity lenses bend all wavelengths of energy, not just visible light. If the gravity lens and background object deviate slightly from a perfect line of sight, they don't produce a ring but a double image of the background object.

In fact, the first known instance of a gravitational lens object was a double quasar, not a ring. In 1979 a team of astronomers led by David Walsh discovered a close pair of quasars in Ursa Major. The astronomers observed two 17th-magnitude quasars separated by a mere 5.7". Walsh and his team observed that the two quasars, designated 0957+561, had nearly identical redshifts. The only plausible explanation was that the two objects were images formed when light from one quasar was bent by a gravitational lens.

Late in 1986 Roger Lynds of the University of Arizona found another example of gravity lensing: giant luminous arcs in the remote galaxy clusters 2242-02 and Abell 370. Although there is some disagreement about what these objects are, they may be incomplete rings caused by imperfectly aligned gravitational lenses.

Until this year no had found an Einstein ring. Now that Hewitt's team has confirmed what Einstein could only postulate, modern technology has caught up with Einstein's prediction. Hewitt's analysis of radio images, conducted over several years, turned up the right object at the right time. But her search for such an object spanned several years and thousands of radio images.

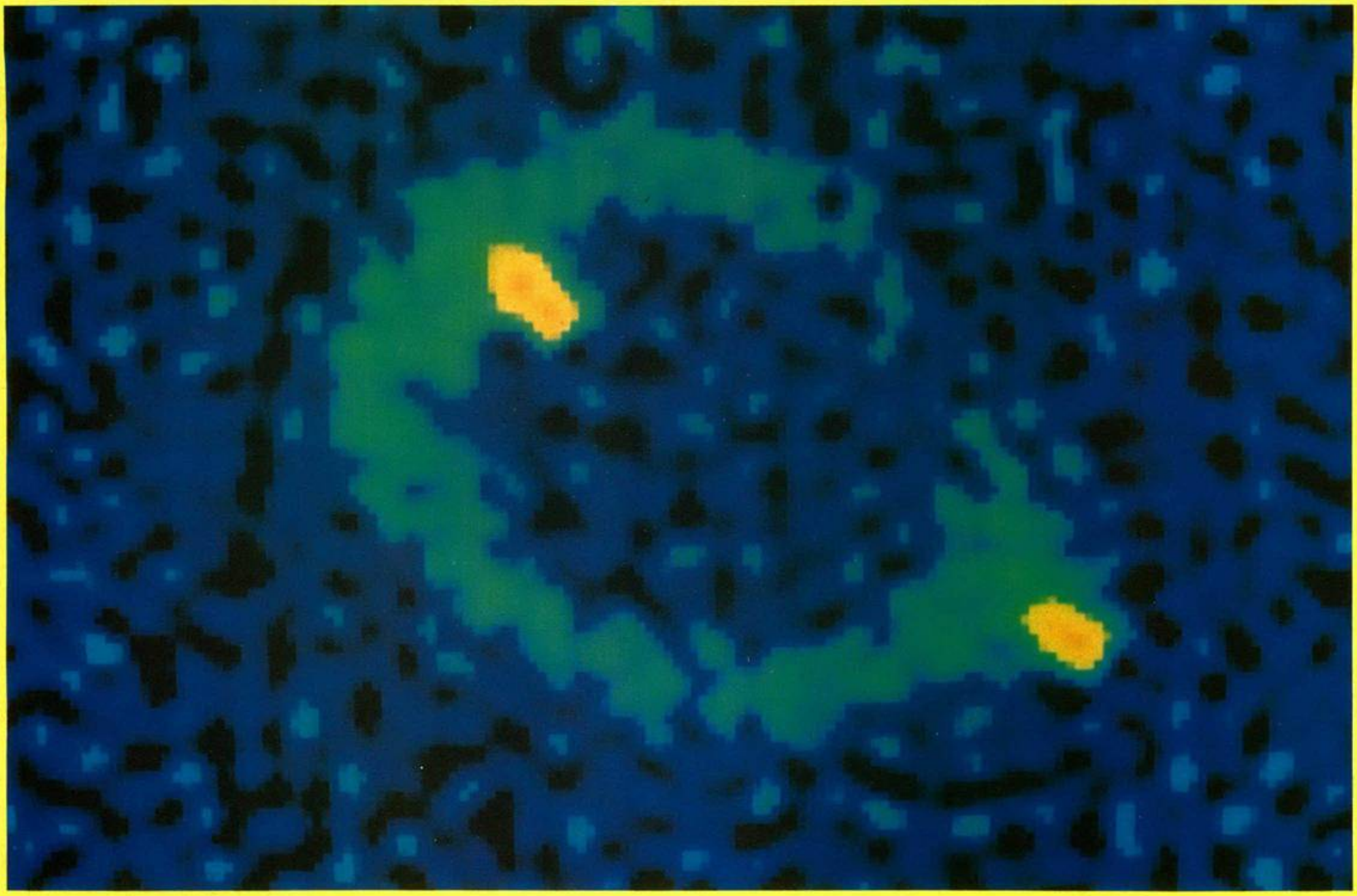
Hewitt began studying astronomy as a student at the Massachusetts Institute of Technology. Working with Bernard Burke, an MIT professor, Hewitt wanted to investigate the dark matter that fills much of the universe. Gravitational lenses provided a way to gauge amounts of dark matter, because the lensing affects how mass is distributed in the lens and therefore how much dark matter lies within it. The more dark matter in the lens galaxy, the more the galaxy will bend light from background objects.

In graduate school Hewitt used the Very Large Array radio telescope near Socorro, New Mexico, to make two-minute "snapshots" of about four thousand radio sources. This database would serve as a catalog of information that Hewitt hoped would contain some examples of gravitational lenses. Hewitt used a radio telescope because the optical images produced by gravitational lenses are extremely faint. Gravity lenses are much more easily detectable in the radio part of the spectrum because they emit large amounts of energy at radio wavelengths.

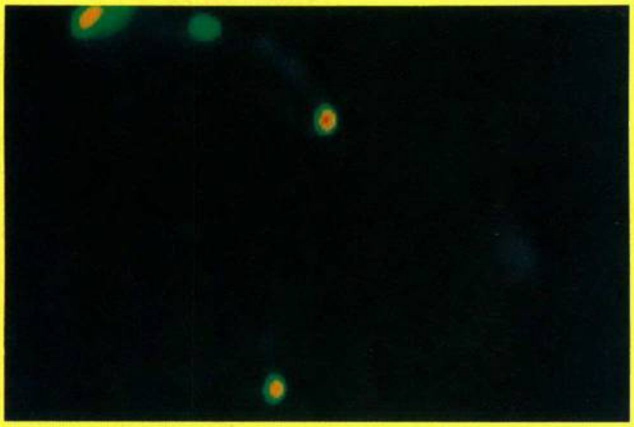
While sorting through the data one day in the autumn of 1986, Hewitt saw a near-perfect ring on her computer terminal. But her initial excitement turned to suspicion. "I thought it might have been due to some software error," she said. "Or maybe something was wrong with the VLA." Then Hewitt correlated the ring object with MG1131+0456, a galaxy cataloged in the Massachusetts Institute of Technology-Green Bank survey of high-energy radio objects.

Hewitt carefully checked all possible explanations and found that only gravitational lensing made sense. She then reobserved the object at two wavelengths and obtained high-quality data for analysis. "Then we needed optical data," she said. "We hoped to find out what sort of object was doing the lensing." Hewitt found that the object's structure resembled a near-perfect gravitational lens. In addition to the ring, Hewitt discovered that the object had an overlapping structure that resembled an incomplete ring.

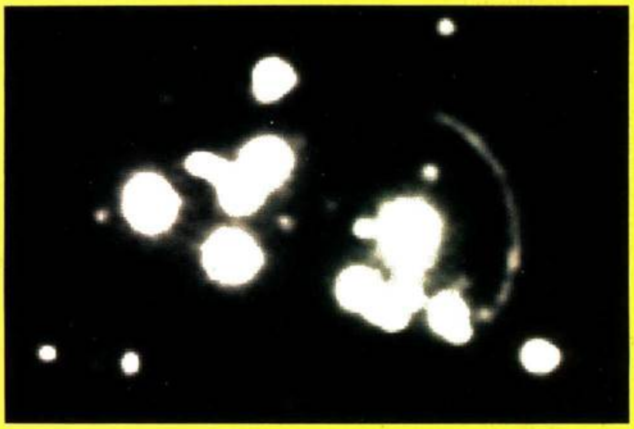
Colleagues Edward Turner and Donald P. Schneider of Princeton, optical astronomers studying gravitational lenses for another project, volunteered to study MG1131+0456 at optical wavelengths and photographed the source with the 4-meter Mayall telescope at Kitt Peak National Observatory in Arizona. After developing the plates, Turner and Schneider found a 22nd-magnitude speck of light at the ring's position. The radio image measured 2" across though, and telescopes can barely show detail smaller than that. This



A COSMIC MIRAGE, gravity rings were predicted by Einstein fifty years ago but not known to exist until now. This ring could reveal information about the size of the universe and the amount of dark matter the universe contains.



THE FIRST KNOWN GRAVITATIONAL LENS was double quasar 0957+561 in Ursa Major, discovered in 1979. The quasar is visible as twin images at top and bottom center.



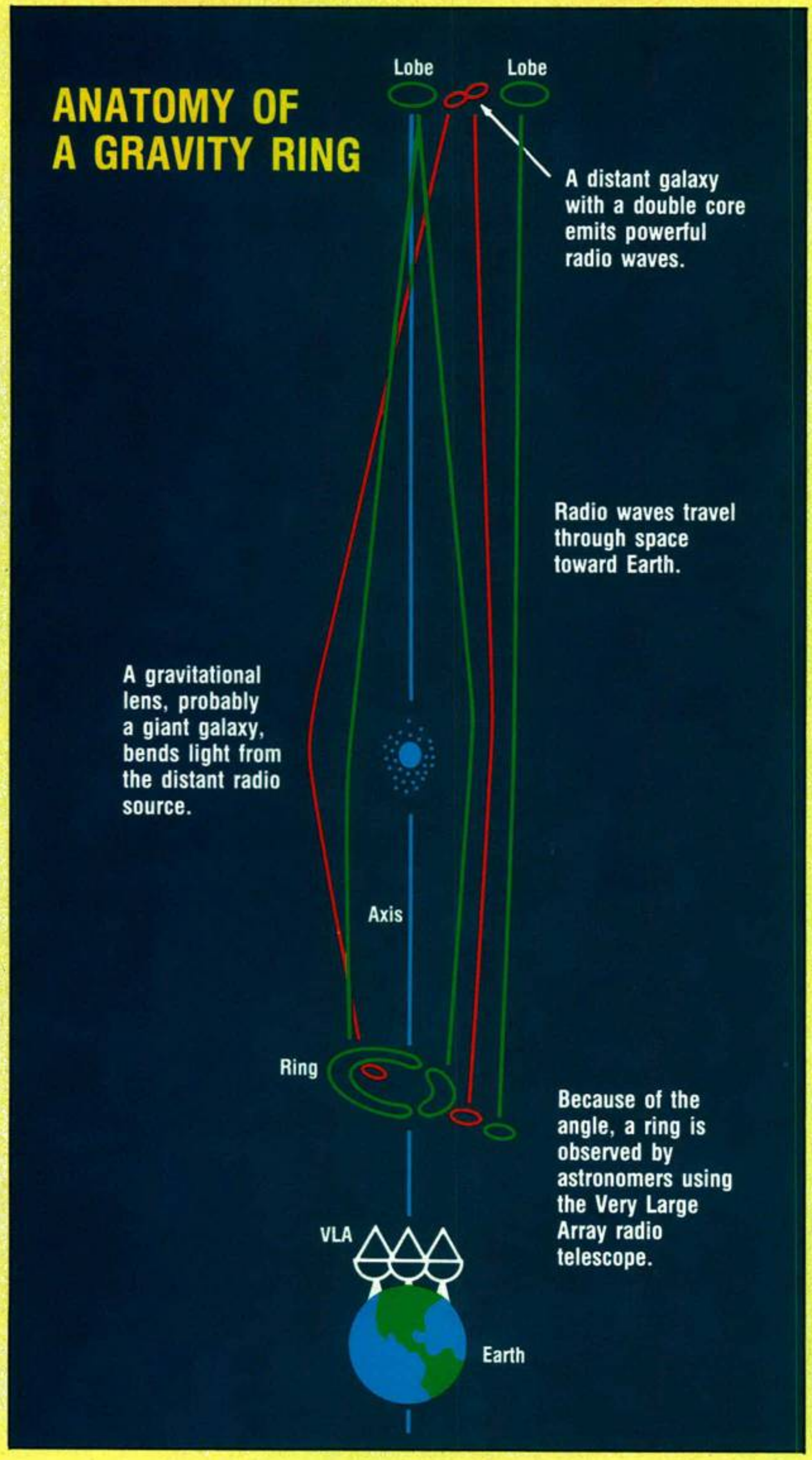
A GIANT LUMINOUS ARC in distant galaxy cluster 2242-02, discovered by University of Arizona's Roger Lynds in 1986, may be caused by a gravitational lens.

made analyzing the optical photographs difficult at best.

"We don't know how much of the optical emission is due to the lens or to the source — the optical equivalent of the radio ring," Schneider said. Furthermore, because of frustratingly bad weather last spring, the two astronomers were unable to obtain a high-quality spectrum that would allow them to measure the object's redshift. Better observations must wait until the spring of 1989.

Currently Turner and Schneider believe the lens is a massive elliptical galaxy. Based on the most recent observations, other explanations for MG1131+0456 seem improbable. Although planetary nebulae and supernova remnants in our Galaxy often produce ringlike structures, the data gathered so far rule these out as possibilities. Although Hewitt cannot rule out an entirely new type of radio object, she and her colleagues believe this improbable.

Hewitt's explanation of the Einstein ring is that a radio source with two energy-emitting lobes lies behind an intervening massive object. The radio



ANATOMY OF A GRAVITY RING

A distant galaxy with a double core emits powerful radio waves.

Radio waves travel through space toward Earth.

A gravitational lens, probably a giant galaxy, bends light from the distant radio source.

Because of the angle, a ring is observed by astronomers using the Very Large Array radio telescope.

source is located so one lobe lies directly behind the lens. This produces the ring. The core of the radio galaxy is itself double and slightly offset from the radio galaxy-galaxy-Earth line of sight. This produces two bright spots in the ring. Another lobe of material in the radio galaxy produces a more distant bright spot in the Einstein ring.

What are the chances of so perfect an alignment of radio source and elliptical galaxy? Hewitt believes the number of faint galaxies is so large that it is reasonable to expect other Einstein rings in other places. Now that the first has been identified, other astronomers will intensify the search for more rings and analyze MG1131+0456 to find clues about the distribution of dark matter and the distance scale of the universe.

"The explanation of this ring is not yet satisfactory," cautioned Edward Turner. "That's because its redshift is not yet known. However, if the distance to the ring is similar to the distances of other lenses, we could draw a powerful conclusion about dark matter: it is more concentrated and lumpy than previously believed." If this is true, then dark matter could play a bigger role in our picture of the universe than ever before imagined. Concentrated, lumpy, plentiful dark matter may distort astronomers' views of distant objects far more than we now think.

Year-to-year brightness variations in the gravity lens could help astronomers refine their value of the Hubble constant, the rate at which the universe is expanding. The radio galaxy should appear to flash as it varies in energy output. Lensed by the intervening galaxy, the flashes should occur at different times in different parts of the ring, as the radio waves travel different lengths to reach Earth. Astronomers could compare the difference in flash times, a directly measurable quantity, with the galaxy's redshift. This would tell astronomers how accurate redshift measurements for galaxies are and would allow them to refine their estimate of the Hubble constant.

The lens could also provide insight into the ultimate fate of the universe. Hewitt believes the statistical results from her survey show that only a handful of sources out of many thousands in the sky show lensing effects. This implies that the universe does not contain enough galaxy-sized chunks of matter to force it to eventually collapse back on itself. Hewitt believes instead that the universe will continue expanding indefinitely. "I cannot close the universe with these sorts of lumps of dark matter," she said.

Hewitt is anxious to use new technologies to study the ring more thoroughly. The *Hubble Space Telescope* could reveal the optical counterpart of the ring, which would provide important clues to both the distant object's structure and redshift. When the Very Large Baseline Array telescope is completed in a few years, Hewitt hopes it might permit astronomers to make a movie showing changes in the ring's structure. "We may see significant differences in the appearance of this object over times separated by only a couple of years," she said.

Einstein predicted gravitational lenses fifty years before astronomers had the technology to find them. Now that Hewitt has found one, astronomers know that MG1131+0456 is the first of what could be an important class of objects. Future study of gravity rings could contribute significantly to our knowledge of the content, size, and ultimate fate of the universe. ☐

Gerrit L. Verschuur is a freelance writer who lives in Bowie, Maryland. His most recent article, "Will Solar Max *Be Saved?," was published in the October 1988 issue.*

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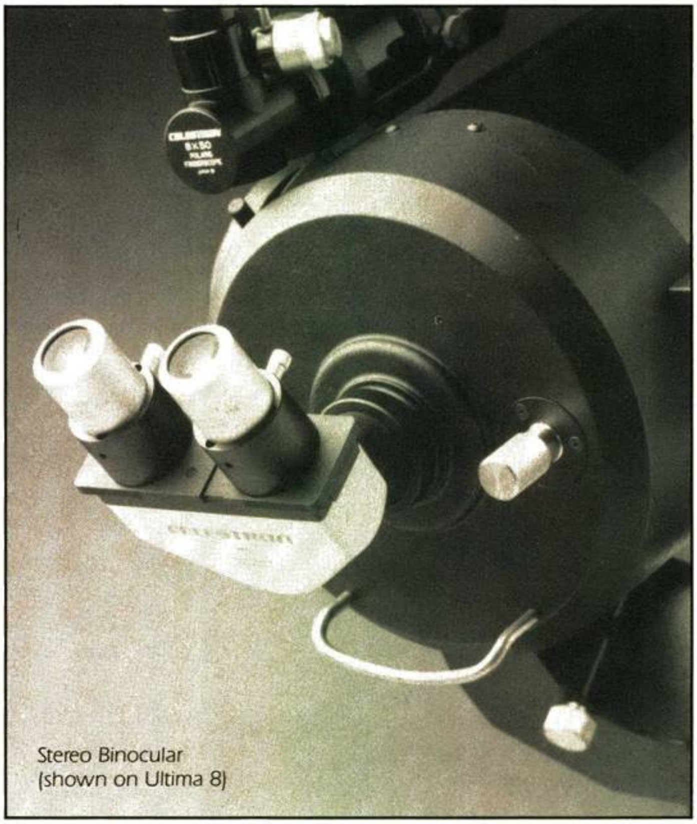
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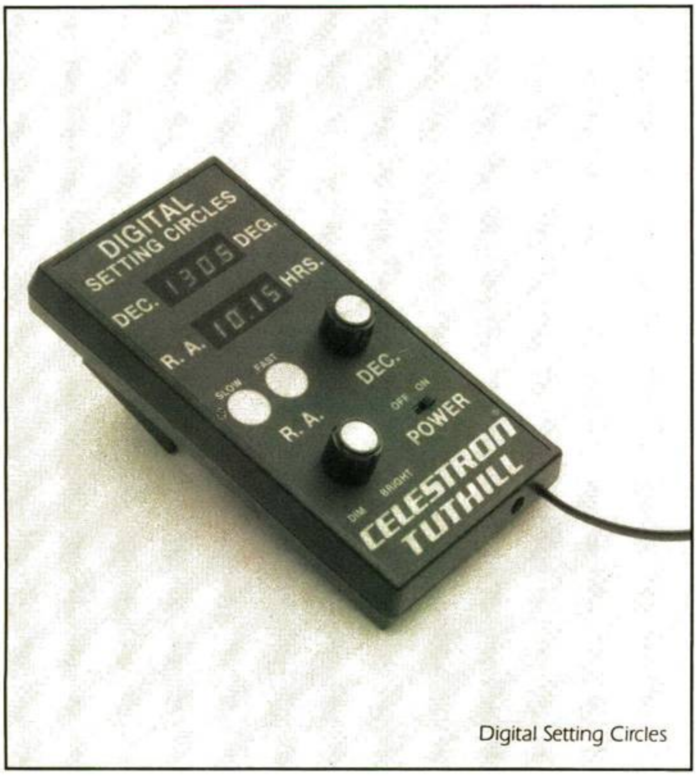

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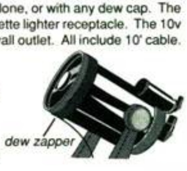

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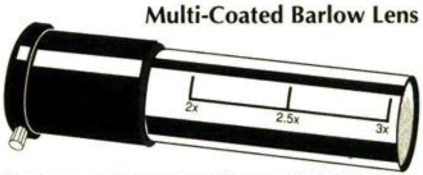

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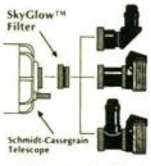

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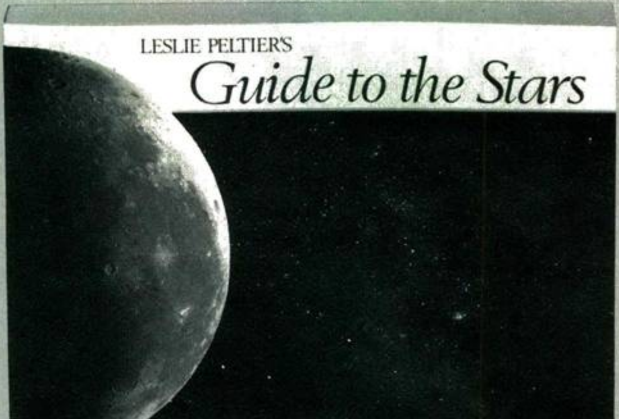

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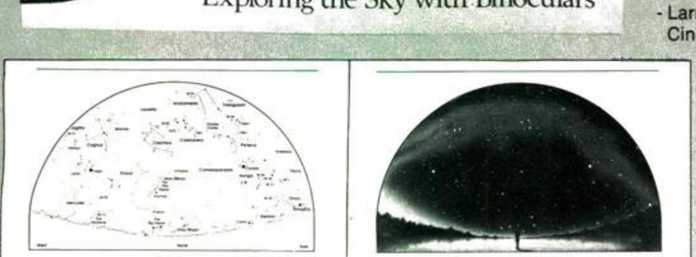

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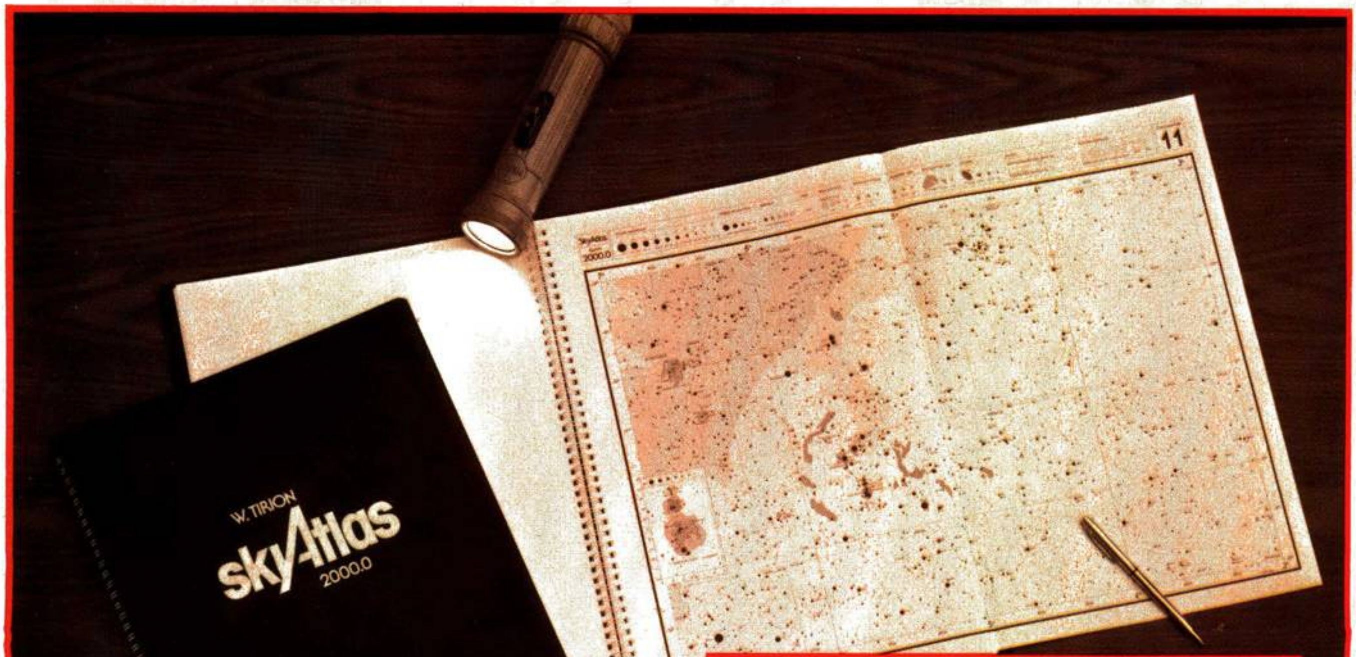
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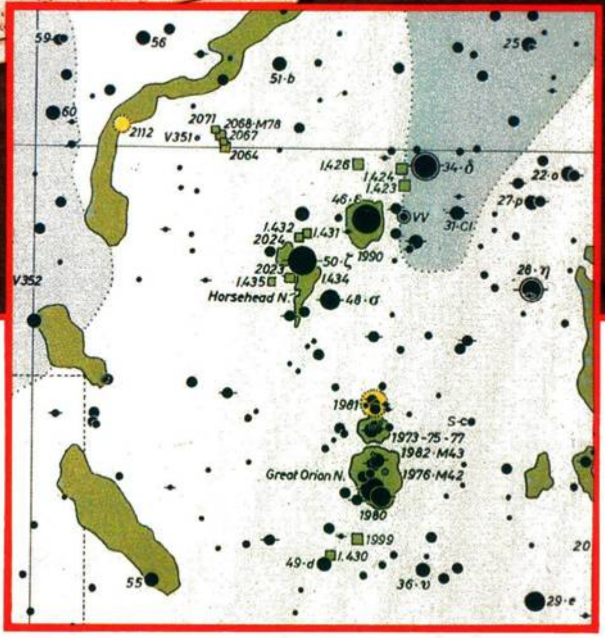
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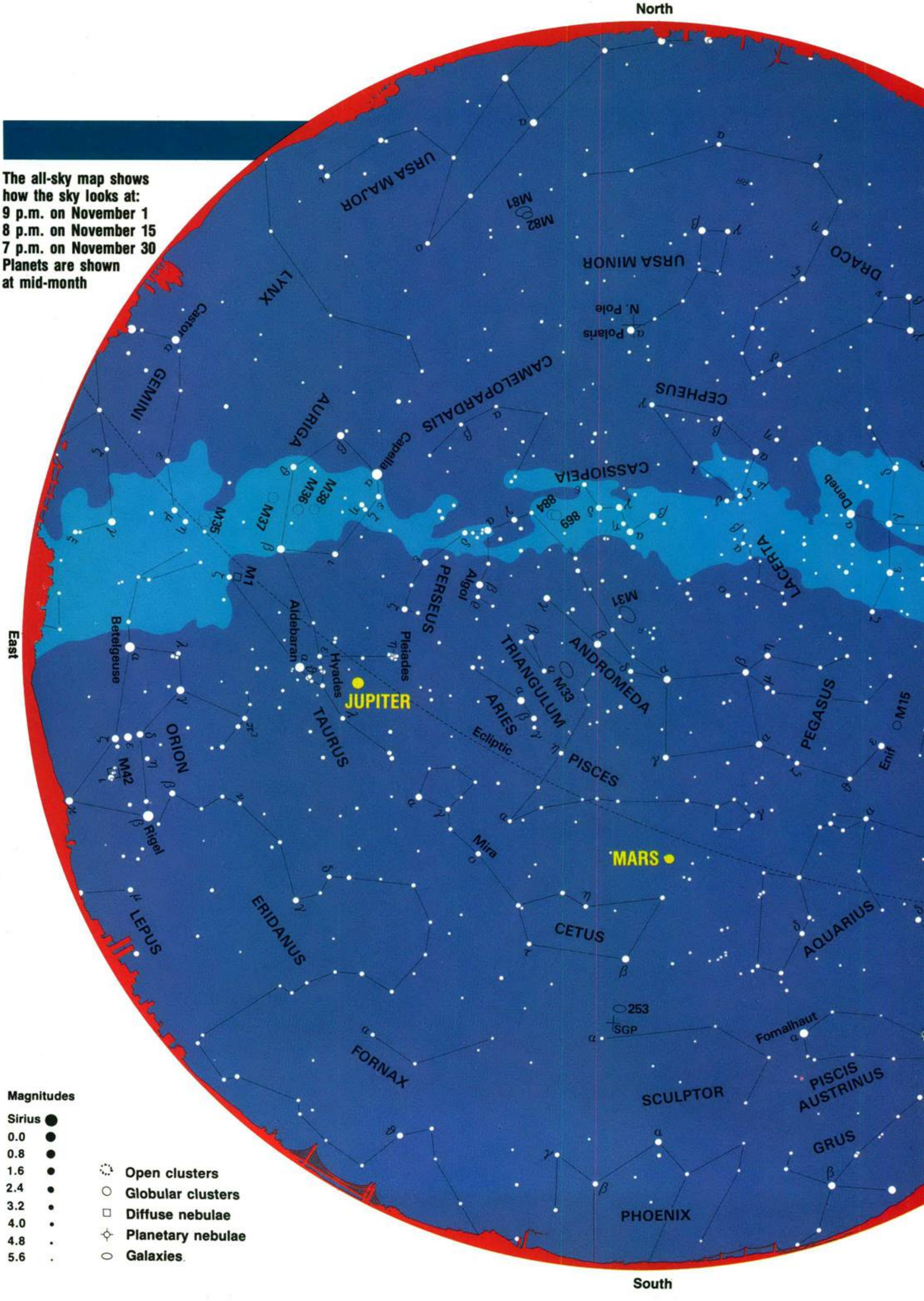
The all-sky map shows how the sky looks at:
9 p.m. on November 1
8 p.m. on November 15
7 p.m. on November 30
Planets are shown at mid-month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M38
M36
M37
M35
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884
869
Deneb
LACERTA
M1
PERSEUS
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M31
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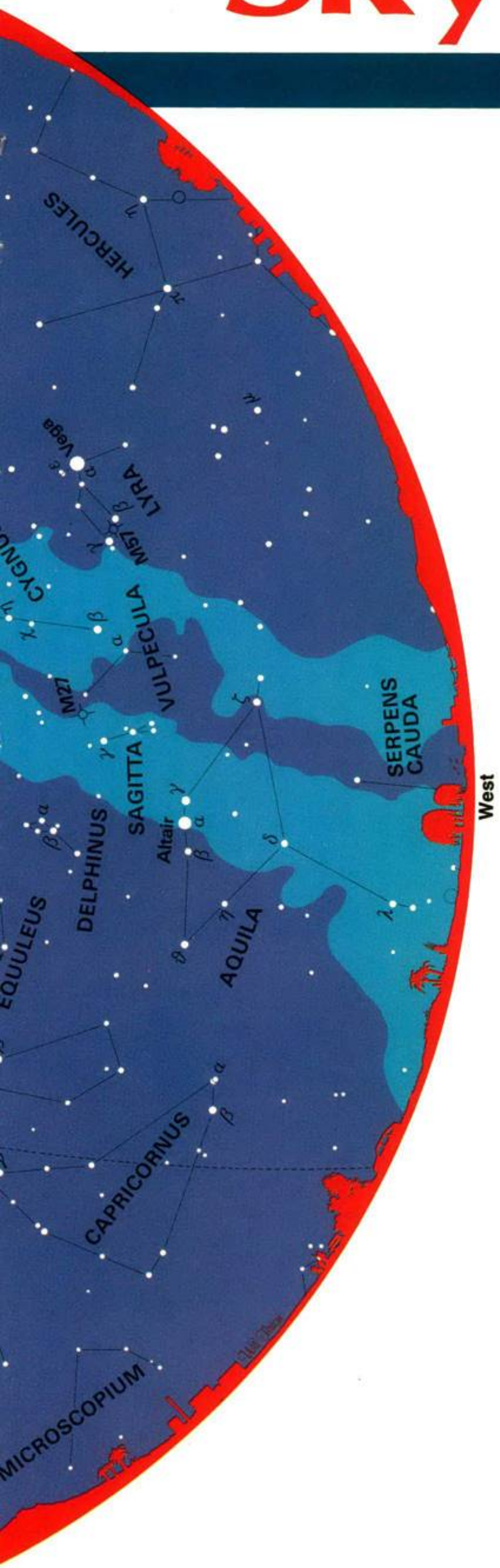


Map Art by Wil Tirion

JUPITER AT ITS BEST

Jupiter arrives at opposition on the night of November 22/23, when it is at its brightest for 1988. The giant planet is located between the Pleiades and Hyades star clusters in Taurus. In a telescope Jupiter appears larger than at any other time this year, which makes seeing details in the planet's atmosphere easier.

AN OCCULTATION OF REGULUS

A waning gibbous Moon passes in front of the 1st-magnitude star Regulus on the morning of November 30. Observers throughout most of North America, except those in the southwestern United States and extreme northeastern Canada, can see the event, although in the East the Sun rises before the occultation ends.

TWO PLANETS AND A STAR

Early in the month the planets Venus and Mercury, along with 1st-magnitude Spica, are prominent in the southeastern sky shortly before sunrise. On the mornings of November 6 and 7, watch as the waning crescent Moon passes by the trio.

LEONID METEORS PEAK NOVEMBER 17

Although at rare intervals the greatest meteor shower of all, the Leonids in most years are a fairly unproductive shower. With the Moon out of the sky this year you can expect to see between about five and twenty meteors an hour in the early morning hours of November 17.

Dates and Times

1 Mercury passes 4° north of Spica, 2 a.m. EST
Last Quarter Moon, 5:11 a.m. EST

2 The Moon passes 0.8° north of Regulus, 10 p.m. EST

4 Moon at apogee (251,699 miles from Earth)
Pluto in conjunction with Sun

6 The Moon passes 5° south of Venus, 10 a.m. EST

9 New Moon, 9:20 a.m. EST

11 The Moon passes 0.5° south of Antares, 3 a.m. EST

16 First Quarter Moon, 4:35 p.m. EST
Venus passes 4° north of Spica, 11 p.m. EST

17 Leonid meteor shower peaks this morning

19 The Moon passes 3° north of Mars, 11 a.m. EST

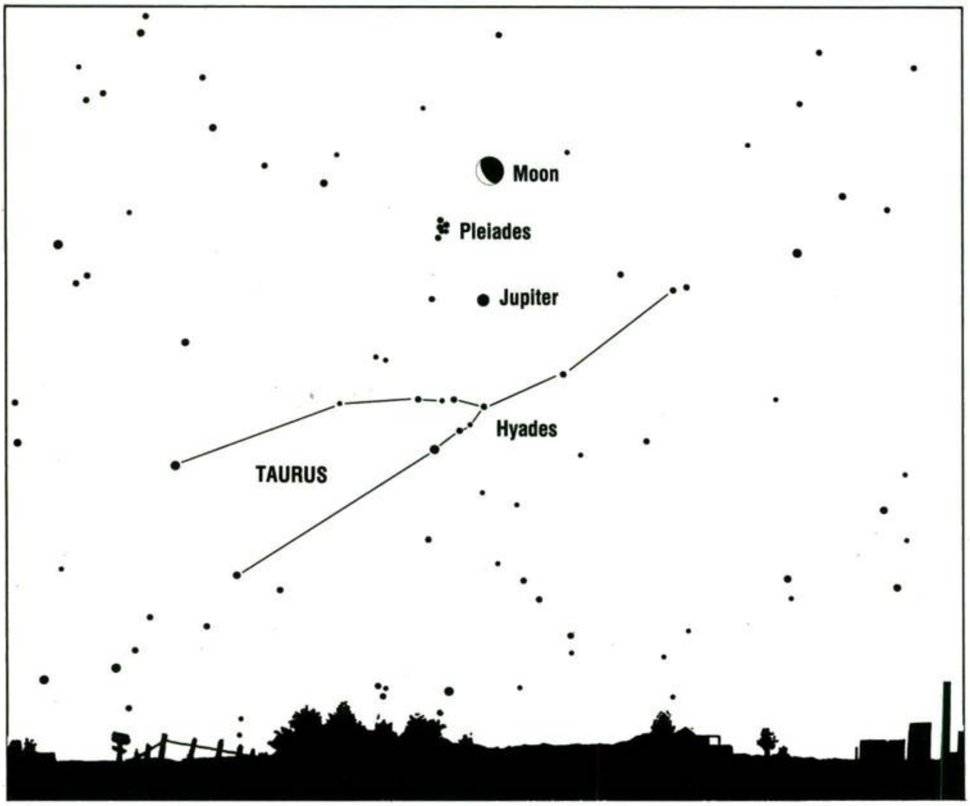
20 Moon at perigee (227,721 miles from Earth)

22 Jupiter at opposition

23 Full Moon, 10:53 a.m. EST

30 Regulus occulted by Moon, 6 a.m. EST

Eye on the Sky by Deborah Byrd



JUPITER REACHES OPPOSITION on the night of November 22/23, when it rises in the east at sunset, shortly after the Moon.

JUPITER AT OPPOSITION

On the night of November 22/23, Earth passes between the Sun and Jupiter. This configuration is called opposition, because Jupiter appears opposite the Sun in our sky. On that night the planet rises in the east as the Sun sets in the west and shines brilliantly at magnitude −2.9.

Jupiter is brighter than any star, and the only brighter planet is Venus, which comes up in the hours before dawn. Jupiter is especially brilliant now because it's only some 375 million miles from Earth, some 180 million miles closer than it was in May when at its farthest from us this year.

Jupiter orbits the Sun five times farther out than Earth does, so the giant planet moves more slowly. Plodding along in its big orbit, Jupiter takes twelve Earth-years to go around the Sun once.

Because we divide our year into twelve months, Jupiter appears at opposition about a month later each year. In other words, in the year it takes Earth to speed around the Sun once, Jupiter moves through one twelfth of its orbit. Earth then has to travel one extra month before it can pass between the Sun and Jupiter again.

Furthermore, because there are twelve constellations of the zodiac, we generally see Jupiter come to opposition one zodiacal figure east of where it was the previous year. In 1988 Jupiter shines at opposition against the starry background of Taurus the Bull.

On the night of opposition, look for Jupiter near the almost Full Moon. That same night the Moon passes in front of the stars in the Pleiades star cluster. The eye alone will have difficulty finding the cluster in the Moon's glare, but binoculars will improve the view.

MARS FADING BUT STILL BRIGHT

Mars can't compete in brightness with Jupiter this month, but it remains very bright in the evening sky. When the month begins, Mars shines at magnitude −1.8, a full magnitude fainter than Jupiter and only slightly brighter than Sirius, the brightest star. By the end of the month Mars has dimmed to magnitude −0.9.

But even at its faintest this month Mars is still conspicuous and distinctive because of its ruddy color and steady light. Look for it in the southeast when darkness falls, shining against the dim background of the constellation Pisces.

A PREDAWN SPECTACULAR

In early November elusive Mercury rises in the east-southeast shortly before sunup. It appears below brilliant Venus and is about one twentieth as bright. The star Spica in the constellation Virgo is also in this part of the sky now, having just emerged from behind the Sun.

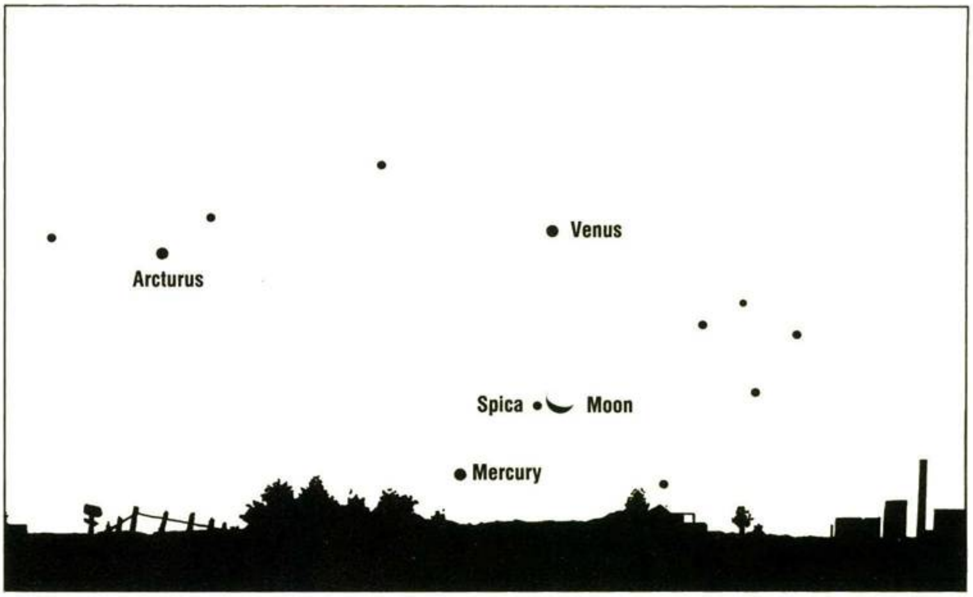
Spica begins the month close to Mercury, low in the predawn sky. By mid-November, when Mercury has fallen back into the dawn, the star rises early enough to appear close to Venus. An especially pretty predawn sky greets early risers on November 6 and 7, when Spica is about midway between the two planets and the waning crescent Moon is sliding past them all.

LEONID METEOR SHOWER

The legendary Leonid meteor shower peaks in the predawn hours of November 17. This is generally a rather sparse shower, but there have been some fabulous Leonid displays in the past. The most recent occurred in 1966, when some observers in the southwestern United States estimated as many as 140 meteors per second! Who knows how many of today's astronomers were "turned on" to the sky by this shower.

The secret to the dazzling irregularity of the Leonids is a great swarm of debris that orbits closely behind Comet Tempel-Tuttle, the parent comet of the Leonids. This comet orbits the Sun once every 33 years and spectacular Leonid displays come that often, when the comet is nearby. The next great display is predicted for 1999.

Still, the Leonids are somewhat unpredictable and worth watching every good year. This year the peak of the shower comes in the early morning for North American observers, when the Moon is also out of the sky. Watch for the Leonids in the early morning hours on November 17 under a dark sky. You should see five to twenty meteors per hour.



A PRETTY MORNING SKY greets observers thirty to forty-five minutes before sunrise on November 7 as a crescent Moon joins Mercury, Venus, and Spica.

NOVEMBER'S PLANETS

Saturn may be found early in November, low in the southwest during evening twilight. It is still in Sagittarius, where it shines at magnitude +0.5. By the end of the month the planet has disappeared in the horizon glow.

Mars is the first "star" to pop into view during the first half of November. It is a reddish orange light in the southeast when night falls, the brightest object besides the Moon until Jupiter comes on the scene.

Mars is located in Pisces now, not far from a faint but remarkably graceful asterism called the Circlet that lies below the Great Square of Pegasus. Mars remains in Pisces through the end of the year.

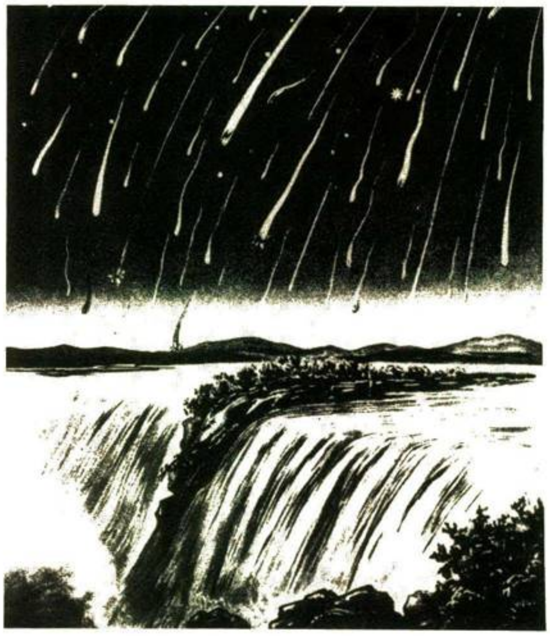
Like all stars, those in Pisces drift progressively westward as the days and months pass. But Mars now has turned eastward again, moving in opposition to the drift of the stars. Thus, similar to a man walking the wrong way on a moving sidewalk, Mars makes little overall progress across our sky. It will come into view at about the same place each evening through the end of the year.

All the while, however, Mars will grow dimmer. Since we passed between Mars and the Sun in September, the distance between our two worlds has been increasing. It's as though we're looking back over our shoulder at Mars now, watching the planet fade in brightness while we flee far ahead in our faster orbit around the Sun.

Jupiter rises shortly after the end of evening twilight early in November. It comes up a little earlier each night until, on November 22/23, the planet reaches opposition and comes up as the Sun goes down. The king of planets is at its best this month. It appears as the brightest "star" in the sky until Venus rises before dawn.

Jupiter, plus the Pleiades and Hyades star clusters located nearby, are good targets for binocular observers. You might count the number of stars in the Pleiades (Seven Sisters) you can see with your eyes alone.

LEONID METEORS FILL THE SKY over Niagara Falls during one of the best meteor showers ever recorded. Expect to see about five to twenty meteors per hour this year on the morning of November 17.



Then count how many more you see when looking through binoculars. Jupiter itself isn't enhanced much by binoculars, but if you hold the binoculars steadily enough, you should pick out at least a few of the planet's four largest moons. This month is also a good time to try to glimpse Jupiter's largest moon, Ganymede, with the naked eye, when Ganymede is near its farthest separation from Jupiter (see Jupiter's Moons on page 68 for times).

Venus rises in the southeast a bit less than three hours before the Sun. At magnitude −4.0, it is more than two-and-a-half times brighter than Jupiter.

Venus is now far ahead of Earth in its smaller orbit around the Sun. It remains prominent through year's end and will not leave the predawn sky until next February. Still, this winter Venus will be low in the sky, at its worst for viewing in many months. The time to enjoy it is now.

Mercury is fairly easy to see below Venus for the first week of November and less easy to see for about another week after that. Then the speediest planet flies into the dawn. It will pass around the far side of the Sun early next month and become visible again in the evening sky before the end of the year.

NOVEMBER'S STARRY SKY

If you've been looking at Jupiter over the past several months, you've seen the Pleiades and Hyades star clusters, which are located in the same direction on the celestial dome.

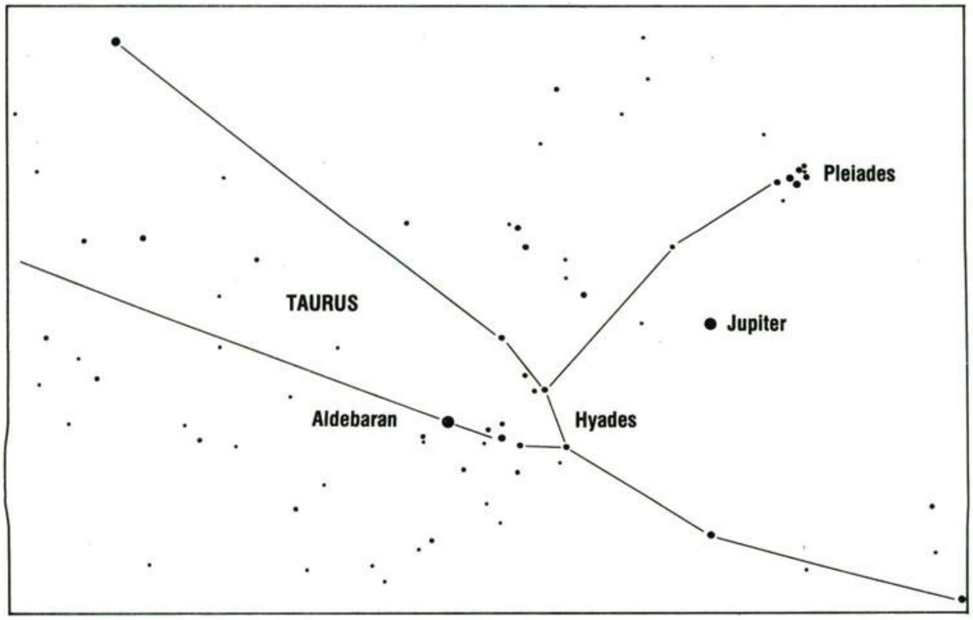
Both clusters appear within the boundaries of the constellation Taurus, and both are striking patterns in our sky. The Pleiades, located in the shoulder of the Bull, are shaped like a tiny, misty dipper. The Hyades, which form the Bull's face, are shaped like the letter "V." In mythology the Hyades represent the half-sisters of the Pleiades.

On the night of Jupiter's opposition the Moon passes in front of the Pleiades. Then, to the eye, these stars are nearly lost in the Moon's glare. Although the Pleiades may look insignificant compared to the Moon and Jupiter, remember that each Pleiad is a mighty sun itself. The Pleiades are located about 400 light-years away and were formed less than 100 million years ago.

The Hyades, meanwhile, are one of the nearest star clusters, only 150 light-years away, but are several times older than the Pleiades. The brightest apparent member of the Hyades, 1st-magnitude Aldebaran, is actually a foreground star that just happens to lie along the same line of sight as the cluster.

The Pleiades and Hyades are open star clusters, and the stars in each were presumably born together from a single giant cloud of gas and dust. But even though their stars may travel together for hundreds of millions of years, both clusters will eventually drift apart. Neither one contains enough stars to create a strong enough bond of mutual gravity to bind the clusters permanently. Cluster members are lost to the pull of passing stars or the powerful tug of the Galaxy as a whole. Or, within each cluster, small stars passing near more massive ones may be accelerated — slung, as from a slingshot — and tossed out of the cluster into the Galaxy. The result is that a cluster "evaporates" over millions of years. ☐

THE PLEIADES AND HYADES are magnificent star clusters when seen with the naked eye or in binoculars. This year the brilliant planet Jupiter joins the two clusters in Taurus the Bull.



Through the Eyepiece by Rick Shaffer

JUPITER'S BIG MONTH

Jupiter reaches opposition on November 22/23. On that night Jupiter rises as the Sun sets, so you'll have to wait about two hours for the planet to climb above the murk and turbulence near the horizon. Jupiter transits at local midnight and remains visible all night.

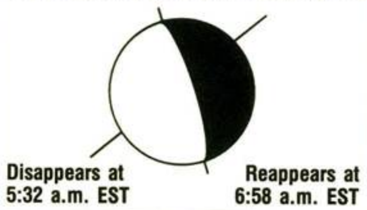
Jupiter's large apparent size makes the planet easy to observe whenever it's reasonably high in the sky. However, this opposition is particularly good for observers in the Northern Hemisphere because it occurs when Jupiter lies near declination +19°, which is only about 5° less than the maximum Jovian declination possible. This means Jupiter will appear high in the sky. You can determine Jupiter's maximum elevation by subtracting your latitude from 90° and then adding Jupiter's declination. For example, out here in Los Angeles our latitude is 35° north, so Jupiter's maximum elevation is $90° - 35° + 19° = 74°$! We'll be seeing Jupiter through nearly the minimum amount of atmosphere — and thus minimum turbulence — as the planet transits the meridian. Also, Jupiter spends more time relatively high in the sky this year compared to years when its opposition occurs at lower declinations. With any luck we should all get many good views of Jupiter without wiggles and blurs.

Your first view of Jupiter should be with a low-power eyepiece. You will immediately notice the rather marked flattening in Jupiter's 49″-diameter disk, which is 7 percent smaller in polar diameter than in equatorial diameter. This is caused by the planet's rapid rotation: the equatorial region rotates in 9h50m, while the rest of the planet takes five minutes longer. A low-power view will also show up to four Galilean satellites arrayed east and/or west of the disk.

Jupiter is the largest of the gas giant planets, those planets that possess extensive atmospheres with at most very small, rocky cores. When you look at Jupiter, you are seeing the cloud tops of the Jovian atmosphere. The clouds consist of ammonia and its compounds, some methane, and a smattering of other organic compounds.

The most prominent features of the cloud tops are the alternating bright zones and dark belts. Even a well-constructed 60mm telescope shows the North and South Equatorial Belts equidistant from Jupiter's equator. Depending on the seeing conditions and the quality of your optical system, you might see irregularities in these belts or the fainter North and South Temperate Belts.

The Occultation from WASHINGTON, D.C.



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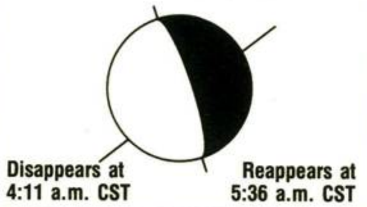
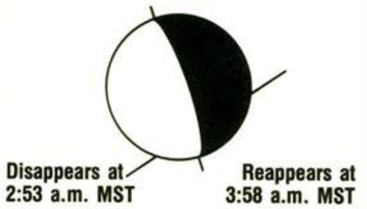
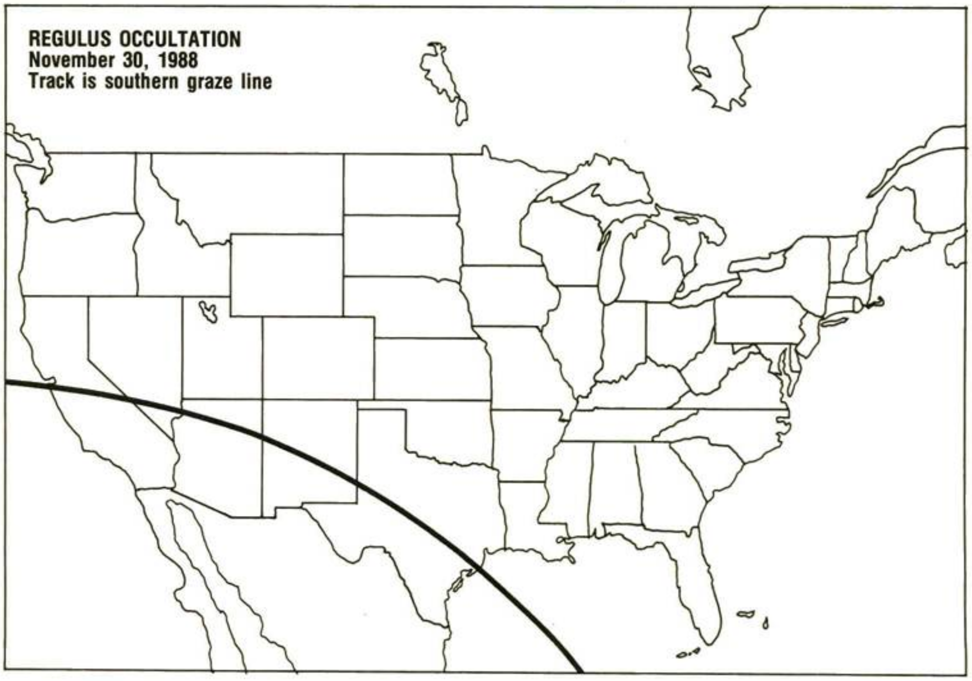


The Occultation from DENVER

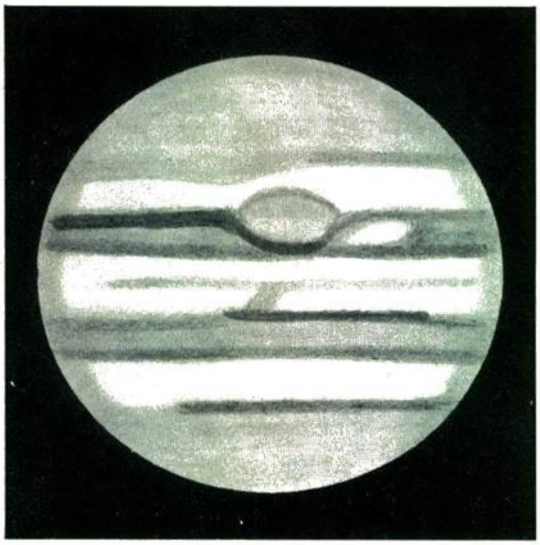


REGULUS IS HIDDEN by the Moon on November 30 for observers north of the southern graze limit (below). However, the Moon's path in front of the star and the time of the occultation depend on your location (above).



With a larger telescope you can observe delicate tendrils of dark material that traverse zones from one belt to another. These are called festoons. Astronomers believe they are caused by turbulence at the border between the low-pressure belts and the high-pressure zones. At these borders the wind velocity is estimated to be 30 to 40 miles per hour, so it is quite turbulent there. Other atmospheric disturbances are white spots, which predominate, and occasional brown spots. Because spots and festoons are seldom larger than 3 to 5 percent of Jupiter's disk and their colors do not contrast well with other features, you'll usually need excellent seeing to detect them.

Finally, we come to the *piece de resistance*: Jupiter's Great Red Spot. This enormous vortex, some 20,000 miles long by 8,000 miles



THE GREAT RED SPOT appeared pale pink when Jose Olivarez sketched Jupiter in early August (above). The table below gives the times for all transits of the Red Spot visible throughout the United States in November.

TRANSIT TIMES OF GREAT RED SPOT

Date	Time
2	1:46 a.m. EST
4	3:24 a.m. EST
4	11:15 p.m. EST
7	12:53 a.m. EST
9	2:31 a.m. EST
9	10:22 p.m. EST
11	4:09 a.m. EST
11	Midnight EST
14	1:38 a.m. EST
16	3:16 a.m. EST
16	11:07 p.m. EST
18	4:54 a.m. EST
19	12:45 a.m. EST
21	2:23 a.m. EST
21	10:14 p.m. EST
23	4:01 a.m. EST
23	11:52 p.m. EST
26	1:30 a.m. EST
28	3:08 a.m. EST
28	10:59 p.m. EST
30	4:46 a.m. EST
12/1	12:37 a.m. EST

wide, is an area of high pressure meandering along in the South Tropical Zone. Its color ranges from brick red to pale salmon, which is the color it has been for the past decade. The predictions of the Red Spot's visibility at right are based on a model of the Red Spot's rotation around Jupiter and may be off by as much as five minutes. The Red Spot is visible for about two hours before and after the times quoted.

Even if the Red Spot is so pale you can't see it, you can detect its presence by observing the Red Spot Hollow. This area of extreme turbulence surrounds the Great Red Spot itself and is the result of the South Tropical Zone being split in two by the Red Spot. In periods of extremely good seeing, observers using 8-inch or larger telescopes should see the Red Spot, the Hollow, and possibly some detail (turbulence) in the Hollow.

BLOCKING THE LIGHT OF REGULUS

On November 30 at 11 UT (6 a.m. EST, 3 a.m. PST) the Moon occults Regulus. The occultation — by a 58 percent lit waning gibbous Moon — is visible throughout North America, except for extreme northeastern Canada and the southwestern United States, the Caribbean, and northern South America. Observers along the East Coast will have to contend with sunlight, however, because the Sun rises near the time the occultation ends.

People along the northern and southern limits of the occultation track, which cuts off the northeast and southwest corners of North America, can see a grazing occultation. Those observers who station themselves exactly on the graze path will see Regulus disappear and reappear several times, as the star passes behind irregularities in the lunar limb. See "Charting Mountains on the Moon" by Robert Reeves, Ron Dawes, and Rick Frankenberger in the August 1988 issue for a complete treatment of observing, timing, and reporting this grazing occultation of Regulus.

MARS PROMINENT IN THE EVENING

Since late September when Mars was at opposition, the Red Planet has been shrinking in our eyepieces and growing dimmer. In November Mars is approximately the same size and brightness it was in late July and early August. However, two factors should make November a better month to observe Mars: Mars is now well past perihelion and thus its worst dust storms should have abated, and Mars is well placed for observing in the early evening this month, so it will be much more convenient to observe than it was last summer.

One phenomenon I've found interesting to observe during past apparitions of Mars is the changing size of the polar cap. Because perihelion was on August 12, the cap should be considerably larger now than it was in August and September. How much larger? To answer that, compare the drawings of Mars you made back then with the planet's appearance now.

The table on page 75 can be used with the chart in August's Through the Eyepiece to determine what features should be visible at the time you plan to observe. Because Earth is overhead at 25° south latitude on Mars this month, most of the Martian features we see are in the southern hemisphere and the equatorial region. Remember that the northern features on a typical map of Mars will be foreshortened when you view them through your telescope. For more on observing Mars, see "Ten Pointers for Mars Observers" in the July issue and "1988: A Great Year for Mars" by Jeff Beish and Donald C. Parker in the March issue.

NOVEMBER'S PLANETS

Mercury was at greatest western elongation on October 26, so you can still observe this rather shy planet for the first few days of November. But you can't afford to dawdle, because Mercury rises only one-and-a-half hours before the Sun on the 1st and just one hour before the

Sun on the 7th. Mercury's disk is 6″ across on the 1st and shrinks to 5.4″ on the 7th. Its phase changes considerably more slowly this month than it did in the last few weeks of October and resembles a ten-day-old Moon. For European and Asian observers, Mercury passes 4° north of the bright star Spica on the morning of the 1st. Those of us in the Western Hemisphere will see the two separated by a bit more than that, because we will observe the event later in the day. Spica and Mercury are at magnitude 1.0 and −0.8, respectively, in the predawn sky.

Venus continues to dominate the predawn sky this month, rising three hours before the Sun on the 1st. During November its phase changes very slowly and closely mimics that of Mercury. Venus' magnitude remains nearly constant at −4.0, and its diameter shrinks from 13.8″ to 12.1″. (The nearly constant magnitude is the result of the shrinking of Venus' apparent diameter being balanced by the increase in visibility of the sunlit side of the planet.) Venus also does a dance with Spica this month, passing 4° north of the star on the morning of the 17th.

For those who wish to make their last observations of Saturn, Uranus, and Neptune for this year, look very low in the southwest just after evening twilight. To possibly observe Saturn in reasonable seeing, begin viewing the planet as soon after sunset as you can find it, so it is as far above the horizon as possible. (Observing during twilight is often very successful because the atmosphere is sometimes nearly constant in temperature over a wide range of altitudes at that time, which minimizes turbulence.) Uranus and Neptune cannot be found during twilight without setting circles, so wait until dark to observe those planets.

NOVEMBER'S COMETS AND ASTEROIDS

Comet Tempel 2 dims from approximately 9th to 10th magnitude during November. Early in the month the best periodic comet of 1988 is visible very low in the southwest just after evening twilight for observers in the southern half of North America. In the latter half of the month Tempel 2 accelerates northward in the sky, which allows observers farther north to observe it. However, the Moon interferes with comet observations during the last half of the month. To find Tempel 2 this month, use the chart and table at lower right.

No bright asteroids reach opposition in November, though 1 Ceres and 18 Melpomene remain visible in the evening sky.

VARIABLE STAR'S MAXIMUM

We finally have a bit of room for a variable star, and there is no more fitting variable than the first one discovered: Omicron (ο) Ceti, or Mira. This pulsating red giant star varies in visual brightness by about six magnitudes over a period averaging 332 days. Mira was discovered in 1596 by Dutch astronomer David Fabricius, who believed it to be a nova. He named it Mira, which means "wonderful" in Latin. Johann Bayer observed the star in 1603 but thought it was a nonvariable of 4th magnitude and included it in his atlas as ο Ceti. Mira was finally recognized as a variable sometime later. Each cycle of Mira's variation has been observed since 1638.

The next maximum of Mira is predicted to be on or near December 4, so the long-period variable is already starting to brighten toward its probable maximum of 3rd magnitude. We'll cover Mira next month. ☐

MARTIAN CENTRAL MERIDIANS

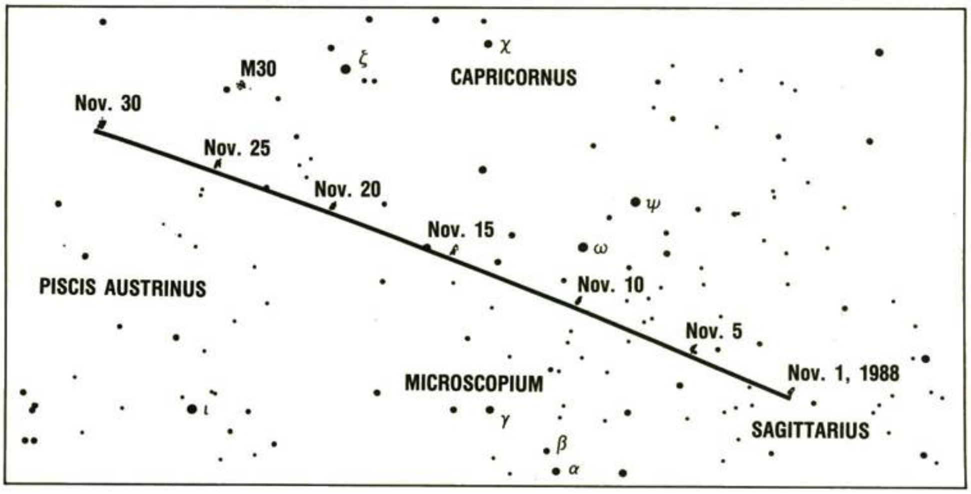
Date	Central Meridian
Nov. 1	319°
Nov. 5	282°
Nov. 9	245°
Nov. 13	207°
Nov. 17	170°
Nov. 21	132°
Nov. 25	94°
Nov. 29	56°

This table gives the central meridian on Mars at 10 p.m. EST (7 p.m. PST) on the date shown (3 UT the next day).

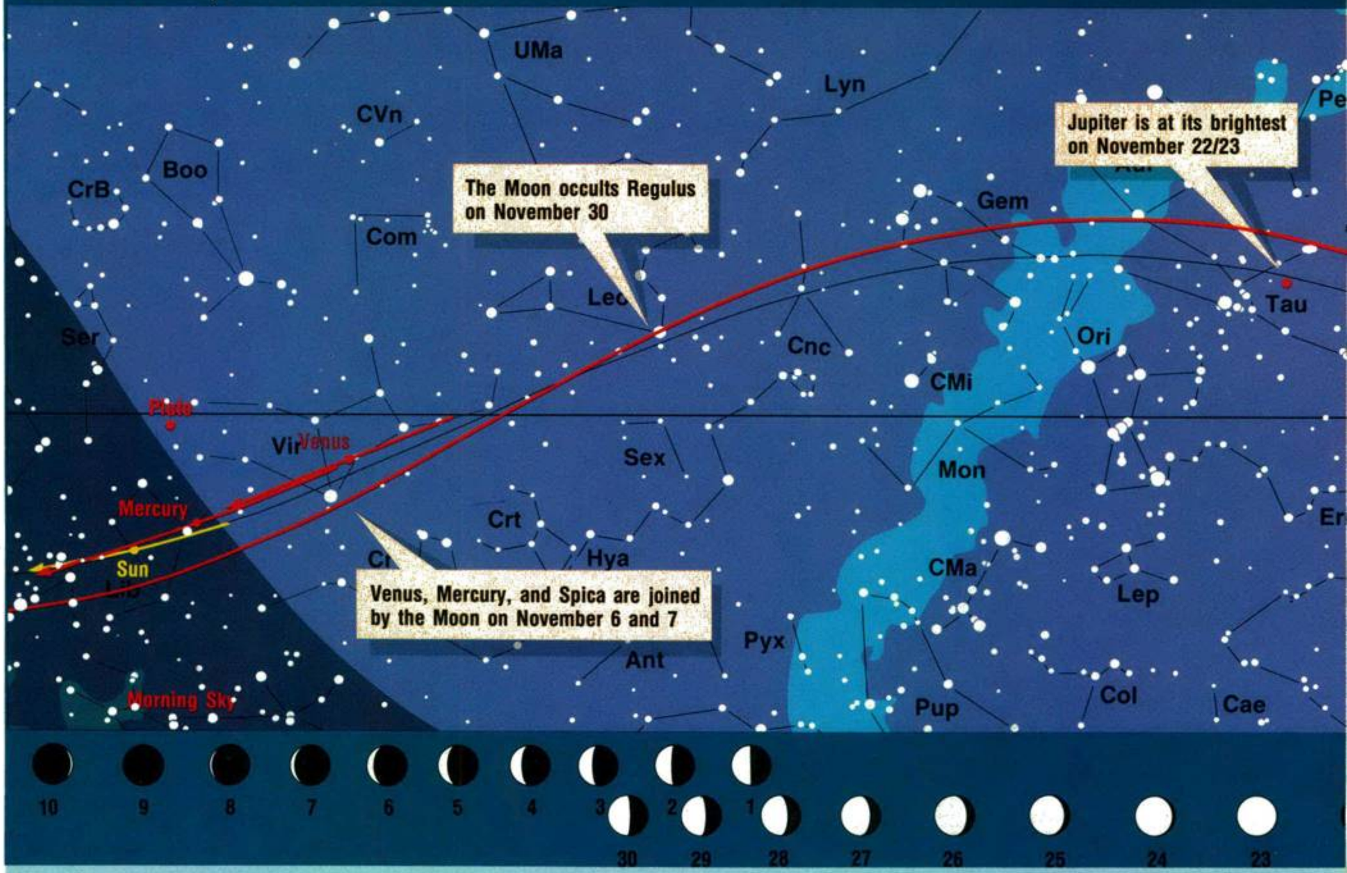
COMET TEMPEL 2 COORDINATES

Date	R.A. (2000)	Dec.
Nov. 1	20h20.1m	−30°01′
Nov. 6	20h38.4m	−29°23′
Nov. 11	20h56.3m	−28°36′
Nov. 16	21h13.7m	−27°41′
Nov. 21	21h30.6m	−26°38′
Nov. 26	21h46.8m	−25°29′
Nov. 30	21h59.4m	−24°31′

COMET TEMPEL 2 swings north this month, where it is slightly better placed for northern observers just after sunset in the southwestern sky.



The Solar System November 1988



The Moon occults Regulus on November 30

Jupiter is at its brightest on November 22/23

Venus, Mercury, and Spica are joined by the Moon on November 6 and 7

UMa
Lyn
CVn
Boo
CrB
Com
Leo
Gem
Tau
Ori
Cnc
CMi
Ser
Pluto
Vir
Venus
Sex
Mon
Mercury
Crt
Sun
Hya
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Lep
Lib
Pyx
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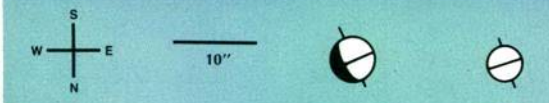
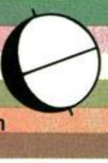
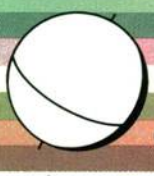
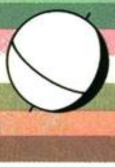




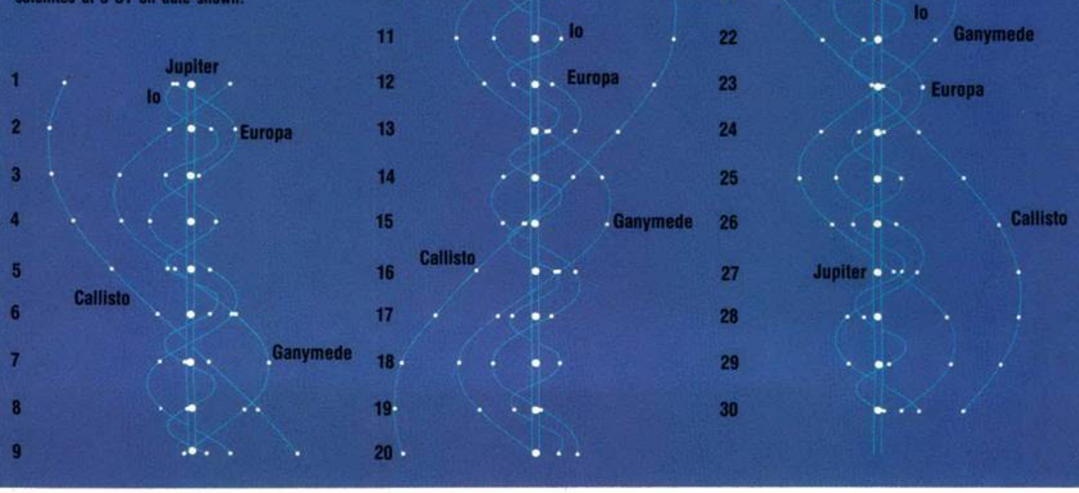


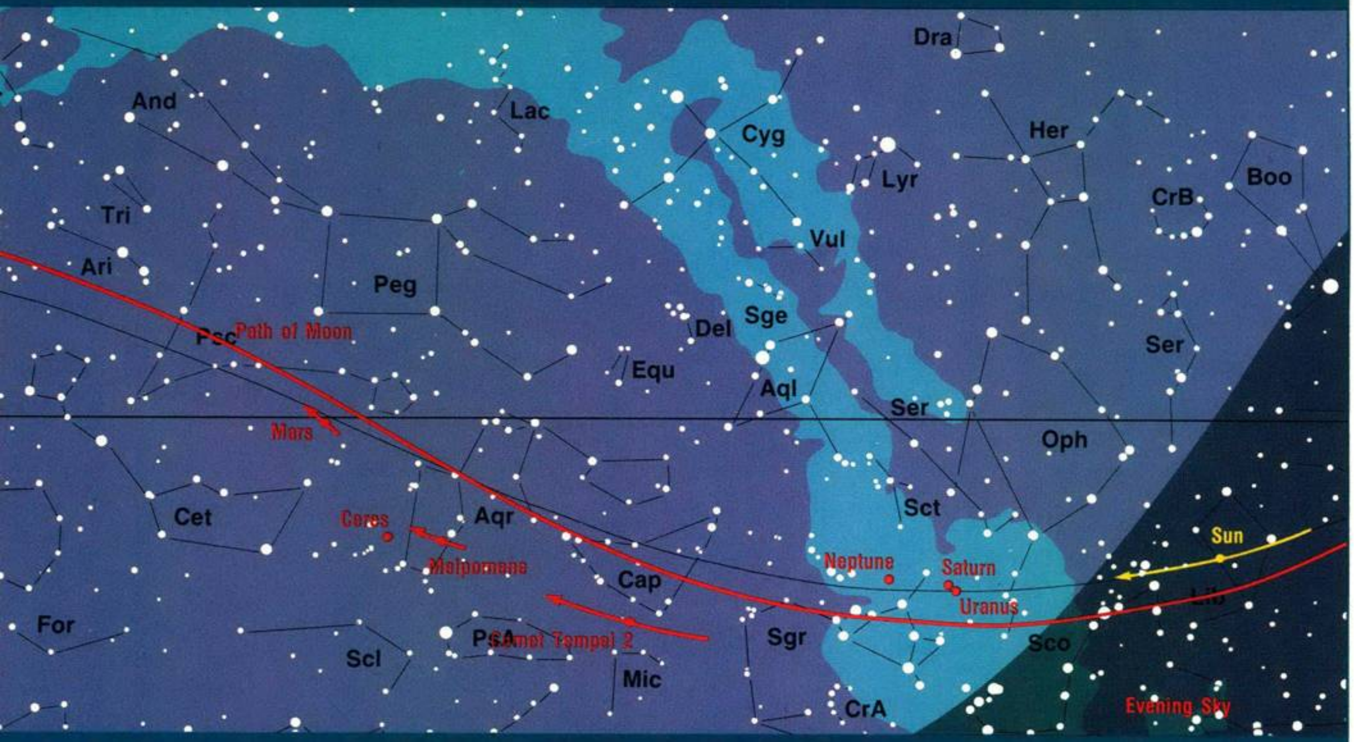


Planet	MERCURY	MERCURY	VENUS	MARS	MARS
Date	November 1	November 30	November 15	November 1	November 30
Magnitude	−0.8	−1.2	−4.0	−1.8	−0.9
Angular Size	6.03″	4.64″	12.9″	18.4″	13.3″
Illumination	75%	100%	83%	95%	90%
Distance (AU) from Earth	1.116	1.450	1.295	0.509	0.704
Distance (AU) from Sun	0.340	0.464	0.719	1.425	1.457
Right Ascension (2000.0)	13h23.6m	16h21.8m	13h15.2m	0h03.8m	0h23.8m
Declination (2000.0)	−6°30′	−22°12′	−6°00′	−1°51′	2°05′

Jupiter's Moons

Dots display positions of Galilean satellites at 3 UT on date shown.

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Sun
Melpomene
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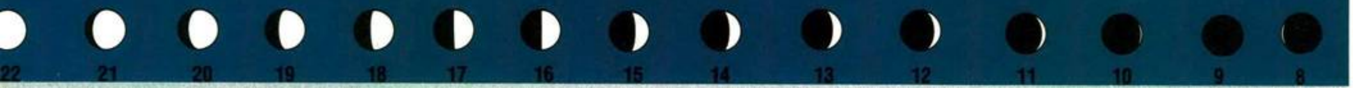
Evening Sky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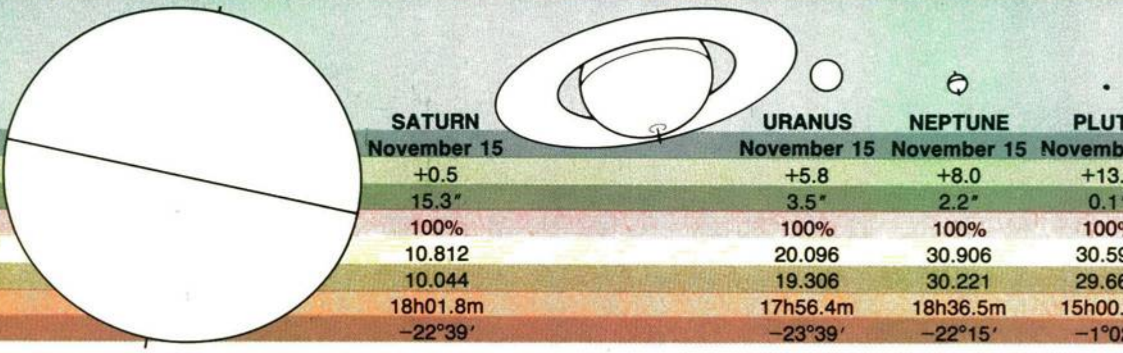
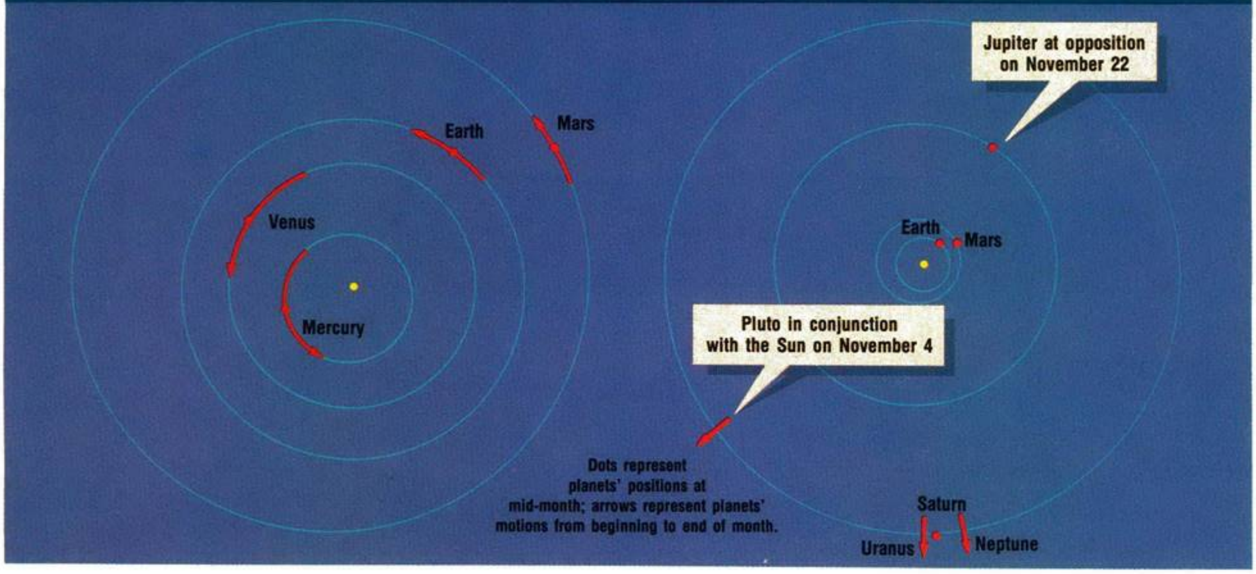


JUPITER November 15	SATURN November 15	URANUS November 15	NEPTUNE November 15	PLUTO November 15
−2.9	+0.5	+5.8	+8.0	+13.8
48.7″	15.3″	3.5″	2.2″	0.1″
100%	100%	100%	100%	100%
4.041	10.812	20.096	30.906	30.597
5.019	10.044	19.306	30.221	29.660
4h01.8m	18h01.8m	17h56.4m	18h36.5m	15h00.9m
19°36′	−22°39′	−23°39′	−22°15′	−1°02′

The Planets in Their Orbits


Earth
Mars
Venus
Mercury
Jupiter at opposition on November 22
Earth
Mars
Pluto in conjunction with the Sun on November 4
Saturn
Uranus
Neptune

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

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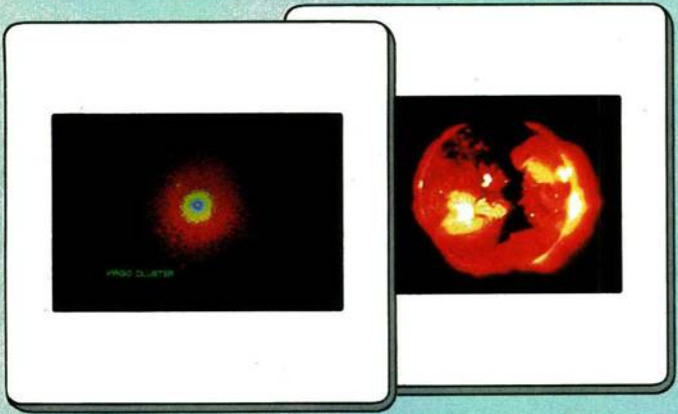

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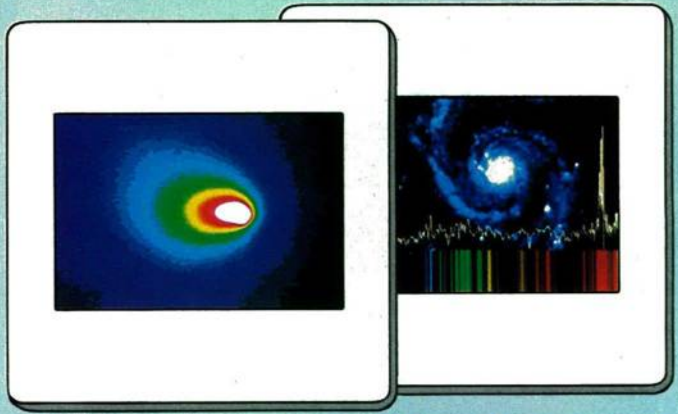

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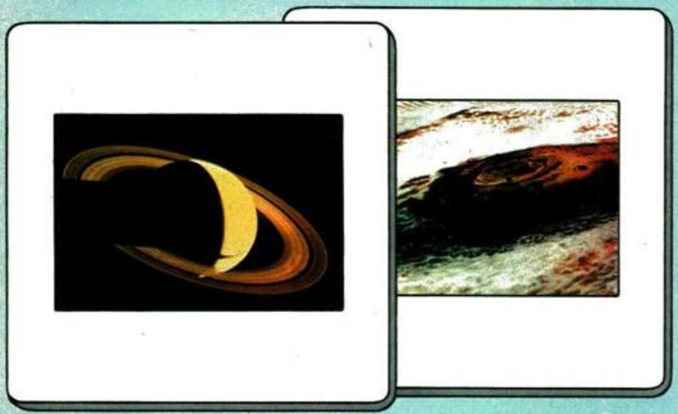

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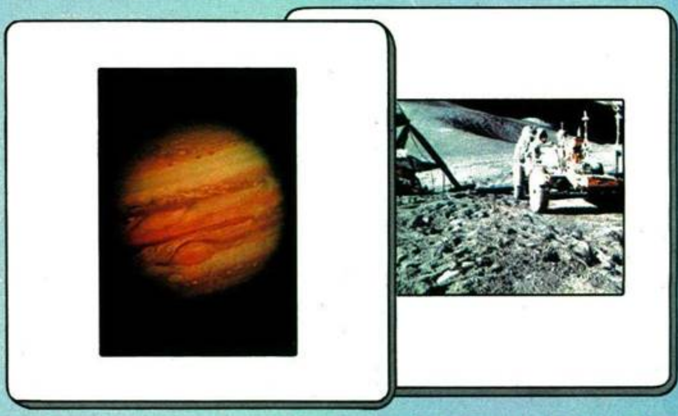

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Table top mount C-65	**$40.00**
Table top tripod	**$30.00**
Tangent assembly	**$225.00**
Chrome Star filter wheel	**$100.00**
Multiple eye pc. holder	**$95.00**
Piggy back mount. 8"	**$30.00**
Piggy back mount. SPC80, SPC102, SPC6	**$35.00**
RFA w/ 22mm or 20mm EP(93614)	**$95.00**
LAR C-90	**$19.00**
Product guide	**$10.00**
Sky Sensor **$399.00,** AC Power supply	**$95.00**
SPC8 half pier	**$89.00**
Tripod slow motion	**$35.00**
Finder scope 16x70 C8	**$219.00**
Finder scope R/A 8x50	**$70.00**
Photo Tripod	**$79.00**

Meade ACCESORIES

784 Quartz drive	**$179.00**
36 S.A. drive	**$85.00**
38 Elec. Dec 2080LX3	**$85.00**
Counter weight 8" or 10"	**$65.00**
600 Battery cell	**$115.00**
Star charts	**$5.95**
Acces Pack #6	**$132.00**
Var Proj cam adaptor	**$40.00**
Dew Star lens shades C8	**$15.00**
Power Star focus motor	**$85.00**
Image corrector 1.25"	**$40.00**
Visual back .96 or 1.25"	**$18.00**

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Meade & Celestron
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices. Both Catalogues $3.

LUMICON FOR HIGH PERFORMANCE

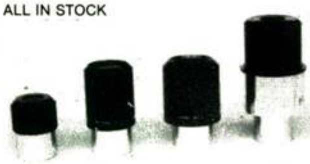
ASTROPHOTO OF THE MONTH

Unguided Konica SR-V 3200 Photo! Southern Milky Way over the Superstition Mountains (east of Phoenix, AZ), 2 minute unguided photo by Andre Bormanis, 28mm f/3.5, LUMICON hypered SR-V 3200.

20mm NAGLER

Also new 12mm & 16mm NAGLERS TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK



Renaissance 4" f/5.5. Telescope	$1395
7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	$89
1.8X or 2.5X Tele Vue Barlow Lens	$89
32mm Plossl, widest true field in 1¼"	$109
55mm 2" Plossl, widest possible field	$190
15mm Wide-Field, 1¼" eyepiece, 65°	$129
19mm Wide-Field, 1¼" eyepiece, 85°	$139
24mm Wide-Field, "superb," 65°	$159
32mm Wide-Field, 2" eyepiece, 65°	$229
40mm Wide-Field, "awesome," 65°	$289
4.8mm Nagler, 82° field	$149
7mm Nagler, 1¼" eyepiece, 82° field	$185
9mm Nagler, 82° field, "the best"	$219
11mm Nagler, 82° field, 1¼" or 2"	$235
13mm Nagler, 82° field, 1¼" or 2"	$249
12mm Nagler, type II, 82°, 1¼"/2"	$249
16mm Nagler, Type II, 82°, 1¼"/2"	$299
20mm Nagler, Type II, 82°, 2" only	$340

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced silver diagonal mirrors & 1¼" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$29.95** 1.52" **$34.50** 1.83" **$39.50**
2.14" **$49.50** 2.60" **$65.00** 3.10" **$89.50**
4.25" **$149.50**

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	$89.50
2" (1.83" mirror)(see photo above)	$145.00

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission=90-97%.

"I CAN SEE THE VEIL NEBULA!"
Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Zepernick, Cresskill, NJ

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 85-95%.

	Standard	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces		$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$59.50	$79.50
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$99.50	$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$99.50	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces		$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces		$199.50
Set of Both premium **DEEP-SKY** and **UHC Filters** (Save 11%), Premium		$159.50
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. 1¼" **$99.50, 48mm**		$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines **1¼" $99.50, 48mm**		$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		$20.00

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount .. $45
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha	(MV)
46, 48, 49mm	$35.00	$29.00
52, 55, 58, 62mm	$45.00	$35.00
67, 72, 77mm	$52.00	$45.00
82mm	$55.00	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

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For phone orders please call (415) 447-9570
LUMICON Products catalogue $2.
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Prices subject to change w/o notice
Hrs: M-F 9am - 5pm; Sat 11am - 3pm

DEEP-SKY ASTROPHOTOGRAPHY

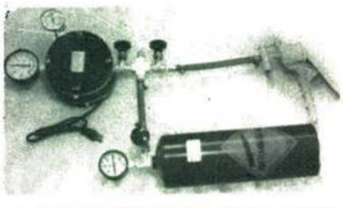
SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.
U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller .. **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent #4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	$169.50
3X Relay Diagonal (see photo)	$79.50
Illuminated reticle eyepiece system	$89.50

Guider for Hasselblad **$350,** Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**
CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

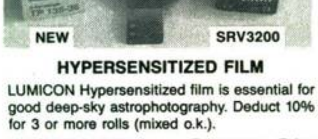
GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**
GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)...... **add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645 **$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. $70
NEW Deluxe Digital Qtz. Drive Correc. **$298**



HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	$10.95
SRV3200, fastest of all, color neg	24	$13.95
Konica SR3200, unhypered	24	$8.50
Konica SR400, fine grain color neg	12	$10.95
3M 1000, fastest slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

LUMICON means INNOVATION

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Livermore, CA 94550 (415) 447-9570

LUMICON® SKY VECTOR™- *NEW!*

Computer-Controlled Digital Setting Circles, only $498

Sky Vector ™
ON · OFF
2137+490
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DEC
DIM
MODE
STAR
LUMICON

LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). Win $10: Identify the object at the coordinates given.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a break-through in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

Incredibly Smart!
thus
Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
- Digital decl. readout to 10 arc-min
- Digital altitude readout to 1°
- Motor drive ***not required!***
- Polar alignment ***not required!***
- Just sight two stars!

The computer's sophisticated program (over 3000 lines of code) determines **everything** from an initial sighting of just two stars!

- **No need** to enter latitude, longitude, siderial time, date, etc.
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080. The computer automatically knows the difference.
- Uses Epoch 2000.0, 1975.0 or 1950.0 coordinates.
- Light weight, only 2 oz. permits mounting near the eyepiece, if desired. Only 2.6"x2.6"x1".
- 9V Battery lasts many nights.

LUMICON SKY VECTOR™ for Meade 2080,2120,C-8,C-11,C-14 *(Specify)* **$498**
For Coulter Odyssey 8", 10", 13", 17½" *(Specify telescope)* **$498**
SKY VECTOR KIT, includes computer, shaft encoders & cables. You must supply adapting hardware. For ATM's only **$469**

Reference catalogues listing coordinates of 1000's of objects
Burnham's *Celestial Handbook*, Vol. I, II, III (Epoch 1950.0) **$36.85**
The *Revised New General Catalogue* (all NGC and IC, Epoch 1975.0) . **$35.00**
Sky Catalogue 2000.0, Vol. II, doubles, variables, deep-sky objects ... **$29.95**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens **$285.00**
LUMICON 2" EASY-GUIDER **$169.50**
2" EASY-GUIDER (Mamiya 645) **$199.50**
Adapter for Hasselblad **$185.00**
Adapter for Bronica SQ-A .. **$175.00**
2" Extension for viewing ... **$26.00**

1.5x, 1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. It multiplies by 1.5x without the included extension tube. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

NEW! LOW PROFILE HELICAL FOCUSERS

FROM
$49.50

LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6" telescope.

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser **$49.50**
LUMICON 2" Helical Focuser **$59.50**
LUMICON Non-rotating Helical Focuser **$79.50**
3 handles (see photo) for non-rotat. focuser **$12.95**
2"/1¼" adapter w/48mm filter threads **$20.00**
2" LUMICON EASY-GUIDER **$169.50**

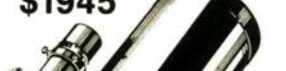
MEADE® TELESCOPES

LUMICON, 2111 Research Dr., #5
Livermore, CA 94550 (415) 447-9570

LUMICON ACCESSORIES

2080/LX6 8" f/6 .. **$1945**
2120/LX6 10" f/6 . **$2495**
Digital readout system for 2080/2120/LX6 .... **add $475**
8200 object memory CAT computer .... **add $1195**

NEW 2080/LX6 $1945



Meade Model 2080/LX6: The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

MEADE SCHMIDT-CASSEGRAIN TELESCOPES

2080/LX5, 8" f/10 w/MCOG ..**$1589**
2080/LX3, 8" f/10 w/MCOG .. **$1389**
2120/LX5, 10" f/10 w/MCOG . **$1995**
2120/LX3, 10" f/10 w/MCOG . **$1799**
2045/LX3 4" f/10 w/LX3 drive . **$795**
#39 declination motor for LX5 . **$109**
#38 (LX3) or #38A (2045) dec. mtr. **$99**
Dew shield - essential! 8" **$65;** 10" **$98**
LUMICON EASY-GUIDER for 2080 .. **$225**
EASY-GUIDER (f/4-f/10) for 2120 **$395**
CAT command control, 8200 objects **$1195**

MEADE SCHMIDT-NEWTONIAN TELESCOPES

MTS-SN6, 6" f/5, #788 drive .. **$589**
MTS-SN6 w/drive, MCOG **$639**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG **$1048**
#36 LX3 hand cntrl. & #38 dec. mtr . **$189**

MEADE NEWTONIAN TELESCOPES

Model 628C 6" f/8 w/motor, 2" focuser **$798**
Model 645C 6" f/5 w/motor, 2" focuser **$698**
Model 826C 8" f/6 w/motor, 2" focuser **$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus. **$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser **$1975**
Model DS-16A w/Sealmaster ball bearings for photography **$2195**
8X50mm finderscope w/brackets for DS-10,-16 .... **$109**

48mm COLORED GLASS FILTERS

These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2" eyepieces. Use adapter for 1¼" eyepieces. AR Coated.

Filter:	Bandpass	Trans	Price
Ultraviolet	320-420nm	85%	**$35**
Minus Violet	420nm-IR	96%	**$29**
Blue Tricolor	340-470nm	80%	**$35**
Hi Perf. Blue	300-540nm	95%	**$35**
Yellow	480nm-IR	98%	**$18**
Green	490-590nm	60%	**$18**
Orange	560nm-IR	98%	**$18**
Red	600nm-IR	98%	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**
Cyan	340-580nm	95%	**$59**
Adapter for 1¼" eyepieces			**$20**

EYEPIECE PROJECTION

These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT. **$32**
1¼" Basic Camera adapter, 2 part system **$32**
0.96" Basic Camera adapter, 2 part system **$32**
1¼" prime Focus adapter, fits 1¼" focuser **$22**
0.96" prime Focus adapter, fits 0.96" focuser **$22**
Camera T-ring, specify 35mm camera type **$12**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼" 50mm Finderscope **$59.50**, right-angle **$89.50**
1¼" straight-thru 80mm SUPER-FINDER ... **$169**
1¼" right-angle version, w/star diagonal **$195**
2" right-angle version, non-rotating focuser .. **$199**
1¼" Deluxe right-angle Super-Finder* **$279**
2" Deluxe right-angle Super-Finder* **$309**
25mm Cross-hair 1¼" eyepiece (12X) **$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver, **$145**
1¼" Amici Prism diag. for correct left-right views **$59.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.... **$26.00**
2" adapter for Criterion 4000, 8000 ... **$26.00**
2" adapter for C-80, C-90, C-100 ..... **$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F **$39.50**
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor **$30.00**
2" adapter for Takahashi E-130, 160 .. **$59.50**

How to Make Great Astrophotos

A solid telescope mount, careful guiding, and your own darkroom add up to the best astrophotos.

by Jack Newton

You want to try astrophotography? Here's the first thing you do. Load your camera with Konica 3200 film, put on your 50mm lens, and go out to a fairly dark site on a moonless night. Stick the camera on a tripod, set the lens to the lowest f/number, and take a 30-second exposure of the sky — of the Milky Way if it's visible.

Thirty seconds, no kidding! You'll get the Milky Way just burned across the film. You can make it even better if you borrow a 2-inch-diameter light-pollution filter and take a 10- or 15-minute shot through it with the camera riding piggyback on a telescope while you track on a star. Believe me, you can make a lot of goofs in the guiding and it won't show up with a 50mm lens.

Getting Started

I think *everybody* who starts out in astrophotography should begin with piggybacked telephoto shots on a telescope. Use the telescope as the guidescope. Camera lens focal lengths are short enough to be very forgiving of guiding errors. Once you have confidence you can guide on celestial objects for long exposures, start taking pictures through the telescope.

Besides a telescope on an equatorial mounting, the basics are an off-axis guider (or guide telescope), an illuminated reticle, a 2x or 3x Barlow to jack up the eyepiece power, an electric declination control (or a *very* smooth and slow manual one), and a variable frequency control to keep the drive chugging along at the right rate.

Guiding Is the Key

Once you've got a stable telescope you're in control of, guide with a magnification that's about five times the focal length in inches. The way I guide is to put a 9th- or 10th-magnitude star in the corner of the cross hairs and keep it there. I rotate the cross hairs until one of them lines up with the drift in right ascension.

If you find that all your correction seems to be in right ascension, then purposely make the star drift an equal distance in declination to keep your star images round. This can also salvage pictures taken with a poor mounting. It gives nice-looking star images and reasonably good pictures. The star images may be *bigger*, but at least they're round, and most people I talk to are very bothered by noncircular star images.

Actual guiding? Your cross hair has four corners. I usually put the guide star where the declination drift will send the star *into* the cross hair. I then leave the star a fractional gap off the hair. That way it's easy to see when the star begins to dig into the cross hair, and with the declination drive I nudge it back out again. If you put the hair right on top of the star, drive errors can make the star wander around behind the hair and you'll never catch it until too late, because the star's smaller than the cross hair.

How much slop you can tolerate depends on your exact setup, but you can find it easily with a set of carefully misguided photos. In my case, I know that if I let the star drift more than one star diameter off the cross hair, I'll see the error on film. But that's not as tough as it sounds, because when I'm guiding at 600x, stars aren't nice, sharp, little dots.

Are Big Telescopes Necessary?

I use a 20-inch f/5 Newtonian I built myself, but I've seen excellent photos taken with 8-inchers to 16-inchers. What really matters is having a rock-solid mounting with decent controls. I find that bigger telescopes just make photography that much easier. You can "overpower" the seeing and even on a mediocre night get some pretty darn good photos.

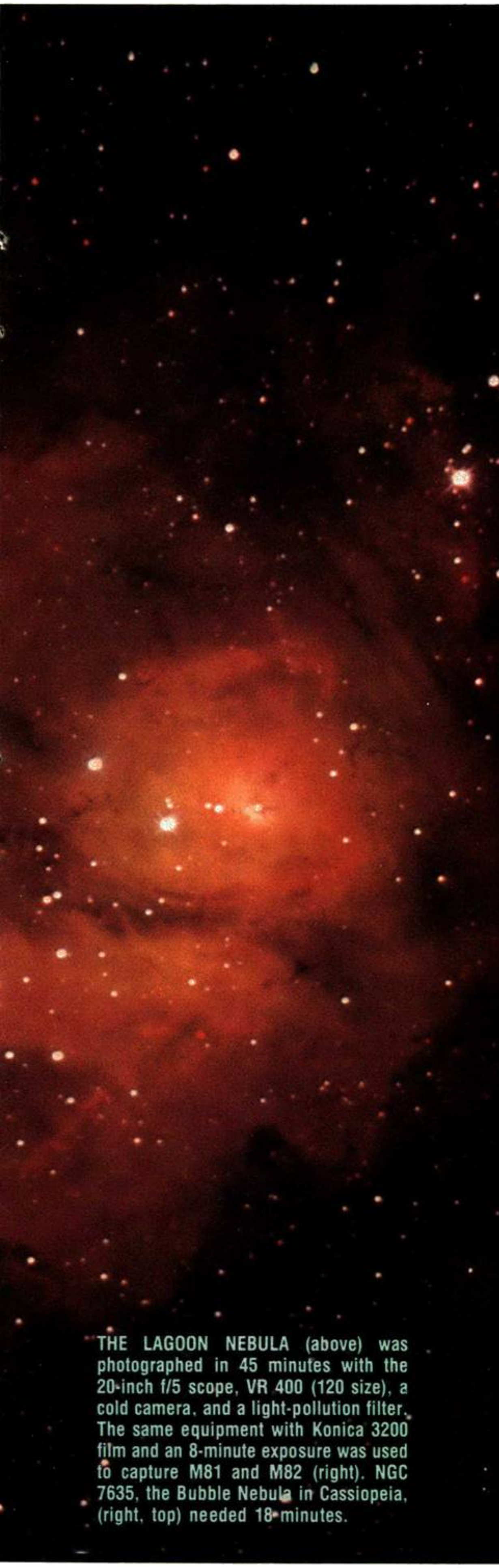
I also use a cold camera of my own manufacture. I've shot almost nothing but cold-camera photos for the last twelve years. They're so much more superior to anything else that I just automatically shoot cold. The only film that's useless cold is Tech Pan 2415 — that has to be gas-hypered. But when I use anything ISO 100 or more, the gain is so dramatic and the color balance is locked in.

I get out photographing about three nights a month, when there's no Moon in the sky. For me, in summer, darkness lasts from about 11:20 p.m. until 2:50 a.m. But by the end of August things are looking better. In winter I rush home from work, grab a bite to eat, and go out photographing. Unfortunately I don't get many good winter nights. Some of the best stuff I've done was in October, when the nights are long but the summer weather patterns haven't yet broken.

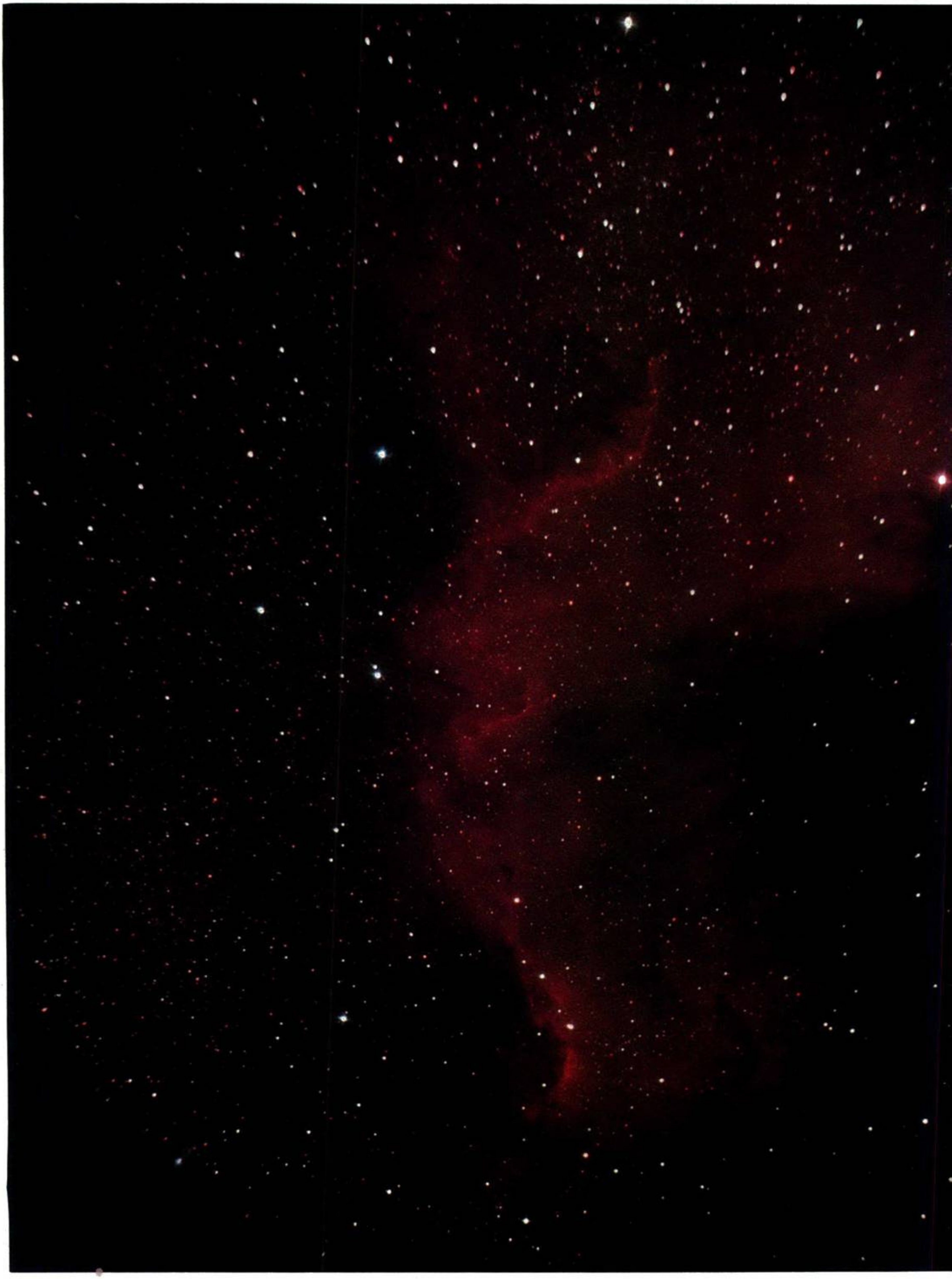
I'm twelve miles from downtown Victoria, British Columbia, and that's city hall. I'm actually only about six miles from the edge of town — it's not bad at all! Most of my photos were taken from home, but I've recently found a darker site a few miles farther out. Wind is difficult at times. You can't photograph in the wind. Anything more than three miles an hour shakes the scope too much.

Right now I'm having a field day with Konica 3200 film. It has better grain structure than any of the fast films such as Kodak's VR 1000, Konica's old 1600, or Fuji's 1600. It is so red and blue sensitive that it makes a fabulous combination with Lumicon's light-pollution filter. In 18 minutes at f/5 with a cold camera it can pull nebulosity out of the sky you won't even find in some of the best Schmidt shots. And when you use the 3200 film to shoot a galaxy like M101 with

TO CAPTURE THE VEIL NEBULA, Jack Newton used his 20-inch f/5 telescope, a 45-minute exposure on Kodak VR 400 (120 size), a cold camera, and a light-pollution filter.



THE LAGOON NEBULA (above) was photographed in 45 minutes with the 20-inch f/5 scope, VR 400 (120 size), a cold camera, and a light-pollution filter. The same equipment with Konica 3200 film and an 8-minute exposure was used to capture M81 and M82 (right). NGC 7635, the Bubble Nebula in Cassiopeia, (right, top) needed 18 minutes.



"MEXICO" in the North America Nebula was photographed with the 20-inch at f/5 with a 20-minute exposure on Konica 3200 using the cold camera and a light-pollution filter.

M33 WAS SHOT on Konica 3200, copied onto Vericolor, duped onto Ektachrome 64, copied onto VR 100, and finally printed!

all its red H II regions, the galaxy looks as if it's got the measles because all those red nebulae stand out.

For other objects I also like Kodak's VRG 400 very much because it has a really good green response — look at the Veil Nebula shot where the film's picking up the ionized oxygen.

Darkroom Doings

An essential part of the whole process is what happens *after* you do the photography. If you're striving for the very best, you've got to do your own darkroom work. On the other hand, I've got great respect for the local one-hour labs that put up with me. They do an awful lot of work to get background color balances right — I give the girls a box of chocolates from time to time! It's just a matter of finding a color lab that will fuss over you.

But if you want to fiddle and fuss with your work, you've got to do it yourself. At least 60 percent of the work is in the printing, not at the telescope. You save money too: 8x10 prints done at home cost me about $3 apiece; a custom lab would charge $14 each. I develop one complete package at a time, which is twenty-five 8x10 prints. I'll take a Saturday and spend about four or five hours making the prints.

Doing it yourself gives you so much more control. For example, the light-pollution filter transmits red easily. This shifts the entire photo to the red and you've got to remove most of that to get a normal photo. In fact, if you work on getting the *blue* right, the red will take care of itself. I start with an 80 magenta filtration and then often add 10 yellow to get the background blue-black.

I'm also working on another thing, though I haven't got a lot of results yet. I shoot a Konica 3200 color photo through a light-pollution filter, followed immediately by a black-and-white one on Tech Pan. Sandwiched, this ought to give a high-density beautiful shot — good color with sharp resolution.

And duping is another piece of darkroom magic you can do. I have been copying my negs onto Vericolor to get a positive image and then recopying this onto VR 100. Boy, talk about Disneyland colors! You can also copy the Vericolor positive onto Ektachrome 64 and then onto VR 100 for a high-contrast, high-color print. This gives a ton of grain, but the star images don't swell very much and the colors just leap off the paper at you. The beauty of home processing is that it encourages you to fuss and fiddle.

Right now it's almost as cheap to make color prints as black and white. The only catch is that you've got to do it all in one go because the chemistry can't sit around once it's mixed.

If outfitting a darkroom looks expensive, try to find a local camera club so you can see just what you really need. Then go ahead and get outfitted. Your family will love it too, because you can take pictures of everyone and print them up. That's just good psychology! □

Jack Newton is an executive with a Canadian department store chain. He has been an astrophotographer for over thirty years and confesses that he's never satisfied with anything he's photographed. He was interviewed by Richard Berry.

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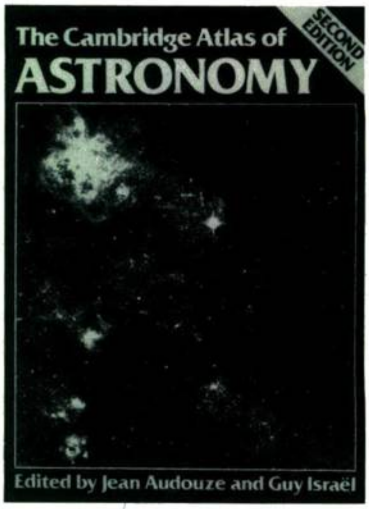

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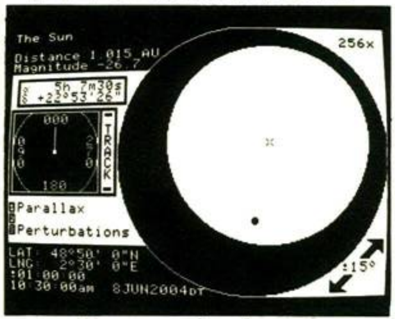

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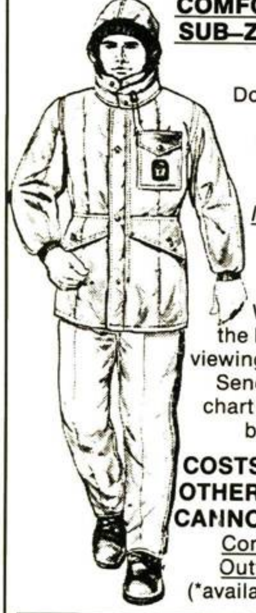

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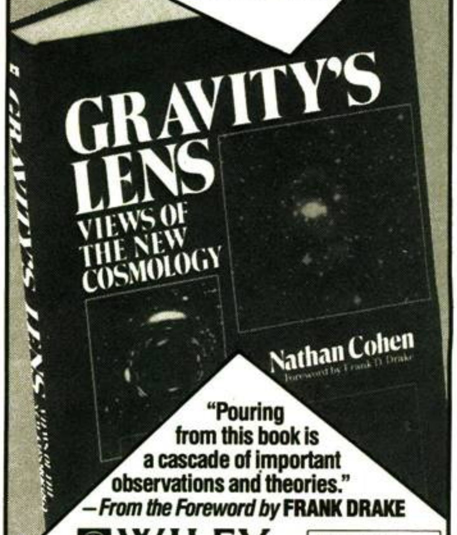

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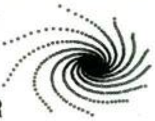

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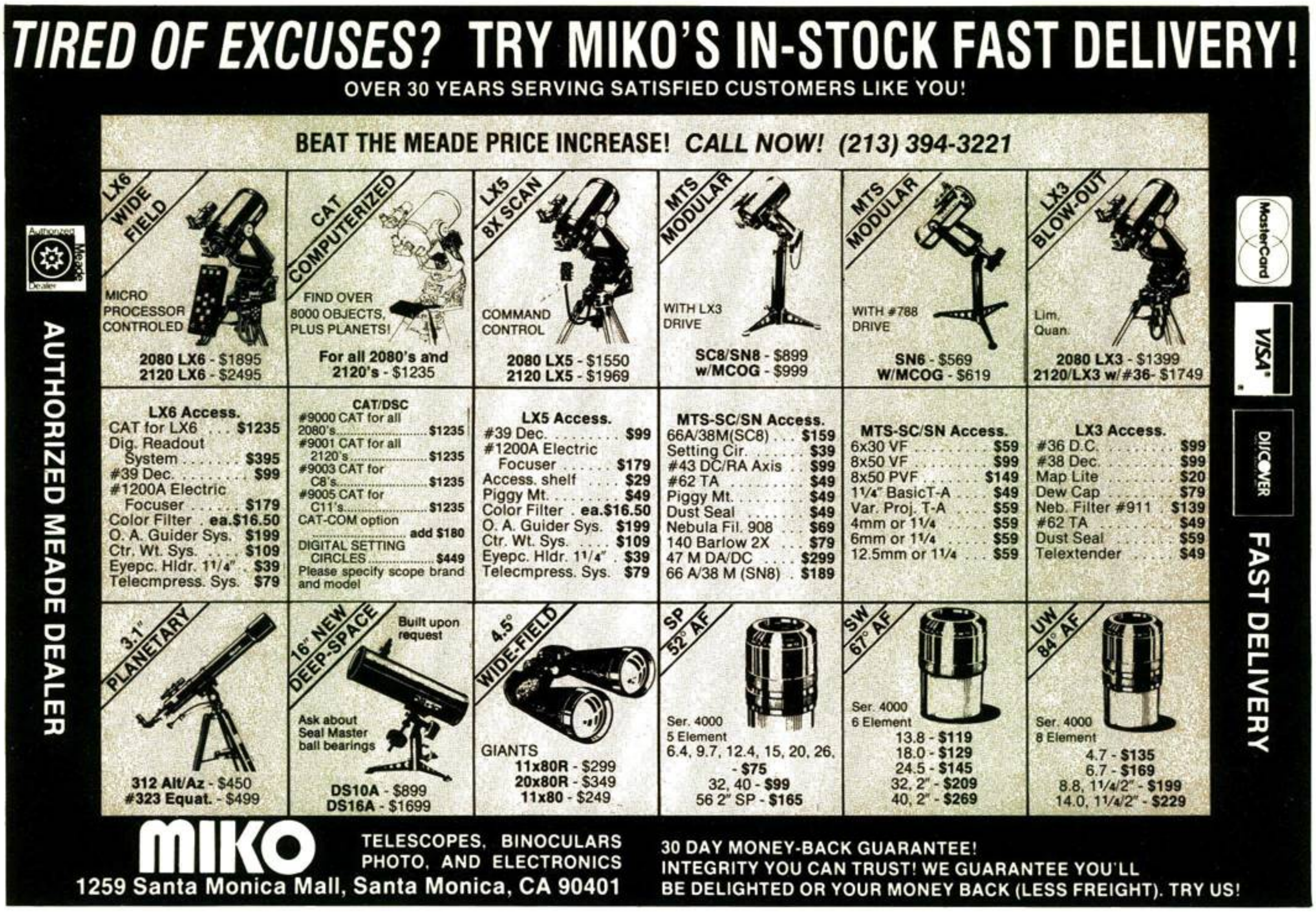

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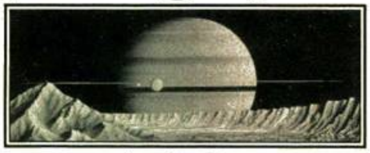

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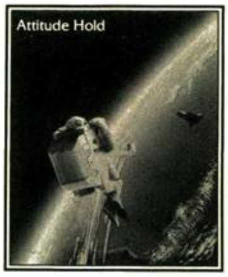

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A New Dimension to Winter Sky Objects

Photographs reveal the faint structure, the breathtaking colors, and the full extent of winter deep-sky wonders.

by David J. Eicher

Astrophotography is powerful stuff. It can extend your visual observing experiences by providing a new dimension to what you see in a telescope. Subtle details, colors, and overall structures too faint to be seen with the eye come alive in long-exposure photographs. By doing a second type of observing — carefully studying photographs — you can see the sky in a new light.

Film provides a fresh look at deep-sky objects in two ways. First, film can store up light during a long exposure. Almost magically this lets a bright image emerge after many minutes of collecting faint light. Second, film records color in faint objects because it retains a broad spectral sensitivity at low light levels. The human eye cannot do this because your retina's color receptors respond only to relatively bright light. When it comes to "seeing" faint objects and detecting color in them, film gives you an important, different look at your favorite objects.

The winter Milky Way contains intricately detailed deep-sky wonders. One of the most beautiful is the Rosette Nebula in Monoceros, a cloud of gas surrounding the bright star cluster NGC 2244. The stars in the cluster are forming out of the surrounding gas, which makes the Rosette one of the nearest and grandest star-making factories known in our Galaxy.

The eye cannot do justice to the Rosette Nebula: only photography reveals its full glory. Small scopes show *the* star cluster but not the nebula. Large scopes reveal faint traces of the nebula but show no details to speak of. Long-exposure photos, however, reveal the Rosette in all its splendor.

The photo on the opposite page shows the Rosette's overall structure and network of fine detail. Dozens of bright and faint cluster stars lie within the nebula's central dark "hole," a void created by the strong winds produced by the cluster's stars. Bright ridges of glowing nebulosity curve around the Rosette's center and backlight tiny, dark specks called Bok globules. (These are clumps of dust slowly condensing into stars.) This photograph transports you far deeper into the Rosette than any telescope can and lets you see the object as a complex, active region with many distinct features.

West of the Rosette Nebula lies Orion the Hunter. A small, inconspicuous patch of light tucked in the Hunter's sword is the Orion Nebula, M42. The Orion Nebula is the brightest star-forming region visible from the Northern Hemisphere.

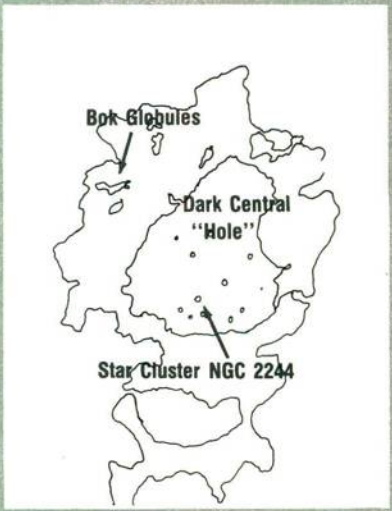
The eye shows the Orion Nebula as a pale, green, misty cloud with several stars embedded in it. Long-exposure photographs reveal that the entire sword of Orion is covered with nebulosity. The top photo on page 97 shows the Orion Nebula lost in a blanket of dust and gas. Faint streamers of nebulosity extend away from the white, overexposed Orion Nebula. The difference between the nebula in a telescope and its shape in a "deep" photo of the region is breathtaking.

A long-exposure photograph reveals that Orion is draped in swaths of nebulosity. The top photo on page 96 shows a veil of glowing light spread across the constellation, as well as five "hot spots" where nebulae are visible. A ruddy glow lies below the belt stars in Orion. A group of nebulae lies in this area, including NGC 2024, IC 434, and the Horsehead Nebula.

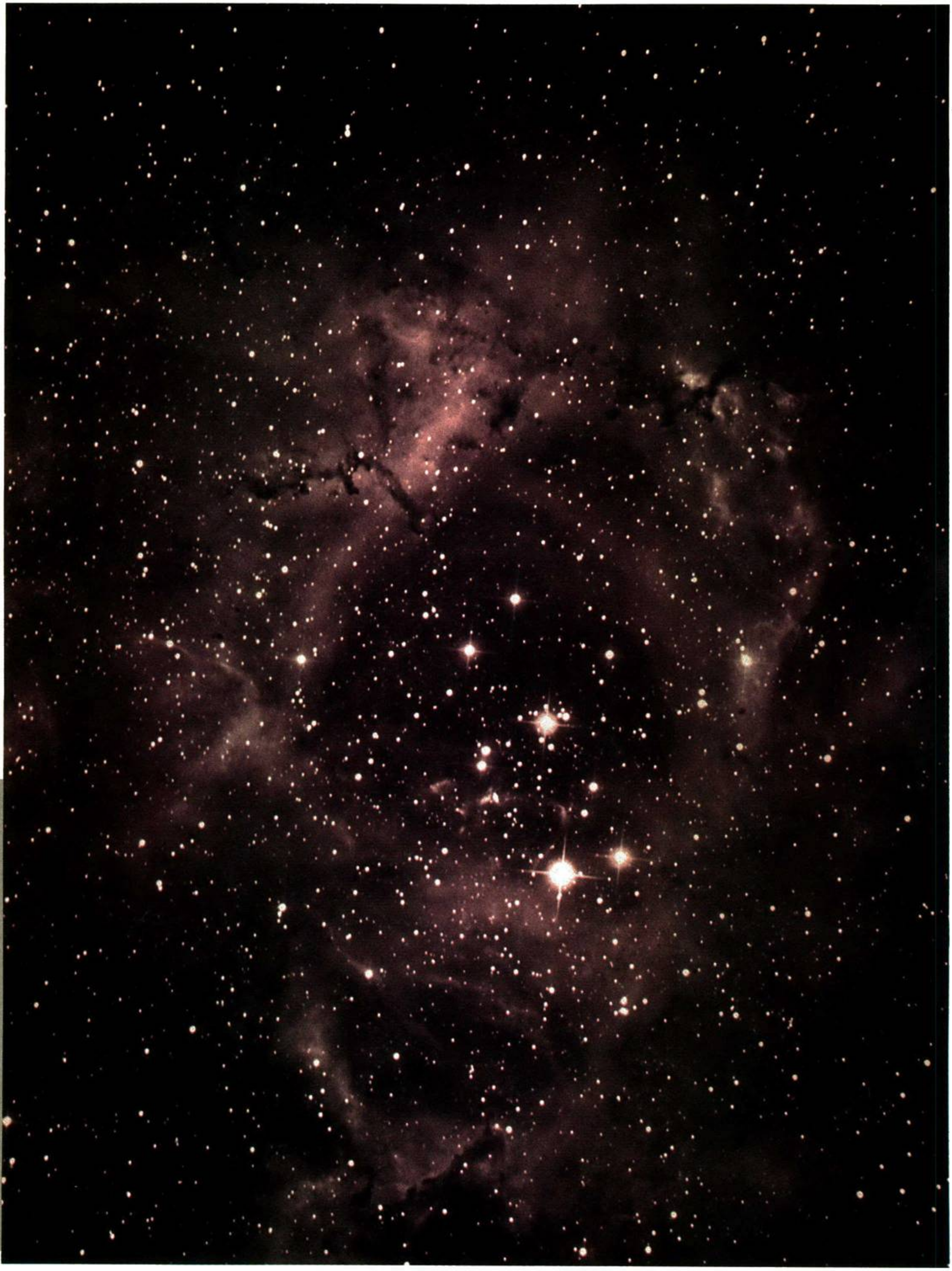
Forming a giant arc in the lower half of the photograph is Barnard's Loop, a bubble of warm hydrogen gas expanding in Orion's Milky Way. The brightest pieces of this object are visible in large backyard telescopes, but photography enables us to see Barnard's Loop as a single object. In the loop, bright areas twist like puffs of smoke. These mark the shock front where warm gas inside the bubble is colliding with the cold material in the surrounding space and causing the nebulosity to shine.

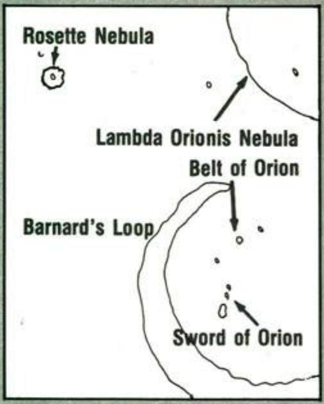
At the top of Orion is a smaller, circular glow called the Lambda Orionis Nebula. This is also a bubble of gas. However, it is younger than Barnard's Loop and appears less spread out. This object is not visible in telescopes: photography alone reveals its existence.

In the vicinity of Zeta Orionis, the easternmost belt star, a glow cuts by a dark patch east of Zeta. Large telescopes show a faint, gray spot of nebulosity southeast of the bright star. The largest backyard scopes, used on a perfect night, reveal the Horsehead Nebula south of Zeta.

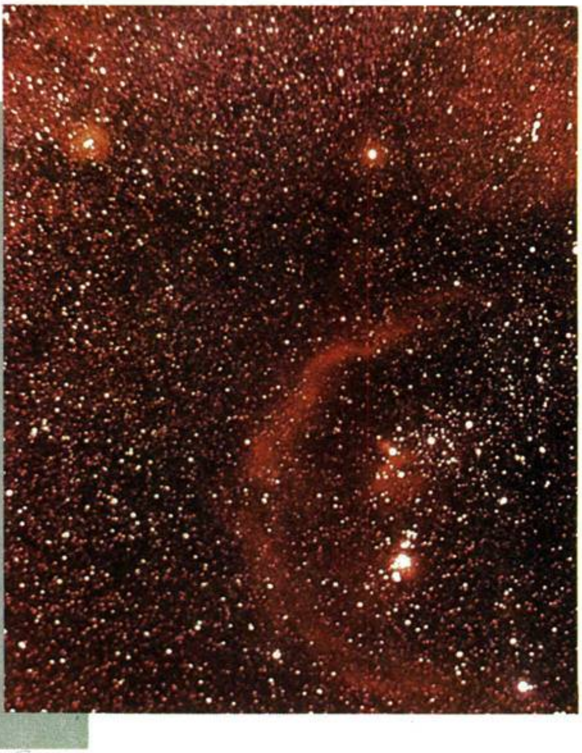


A WREATH OF SOFT LIGHT, the Rosette Nebula in Monoceros shows tiny dark globules in photographs. Only the central star cluster is visible in small telescopes. Photo by Tony Hallas and Daphne Mount.

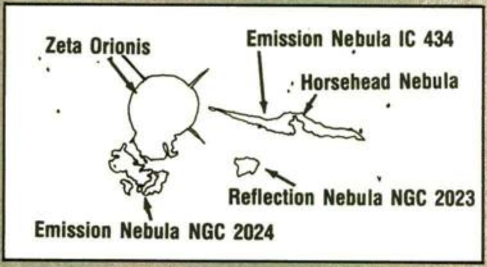




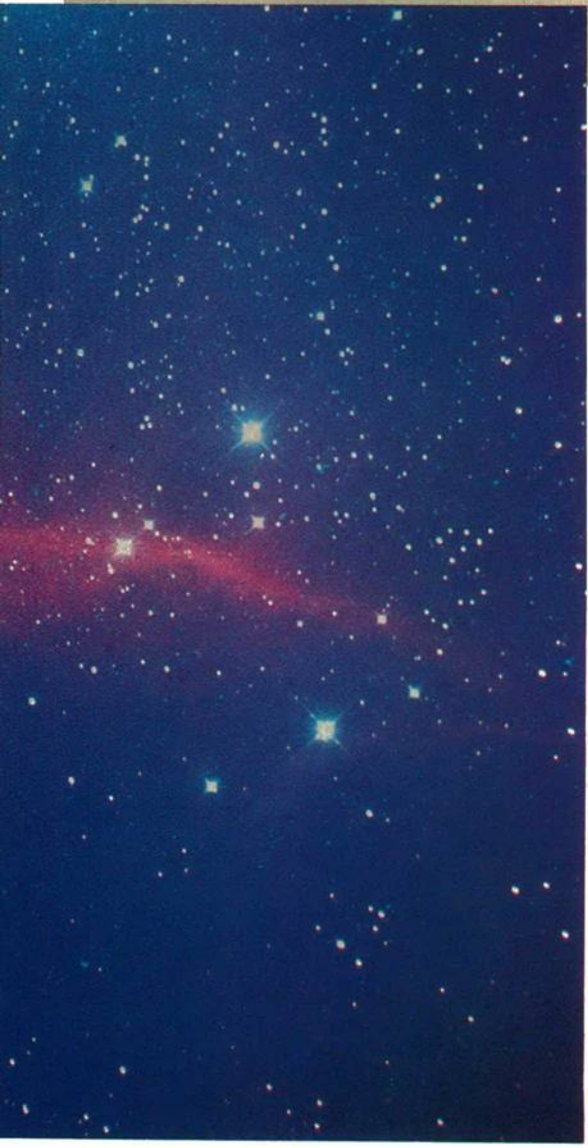
Rosette Nebula
Lambda Orionis Nebula
Belt of Orion
Barnard's Loop
Sword of Orion

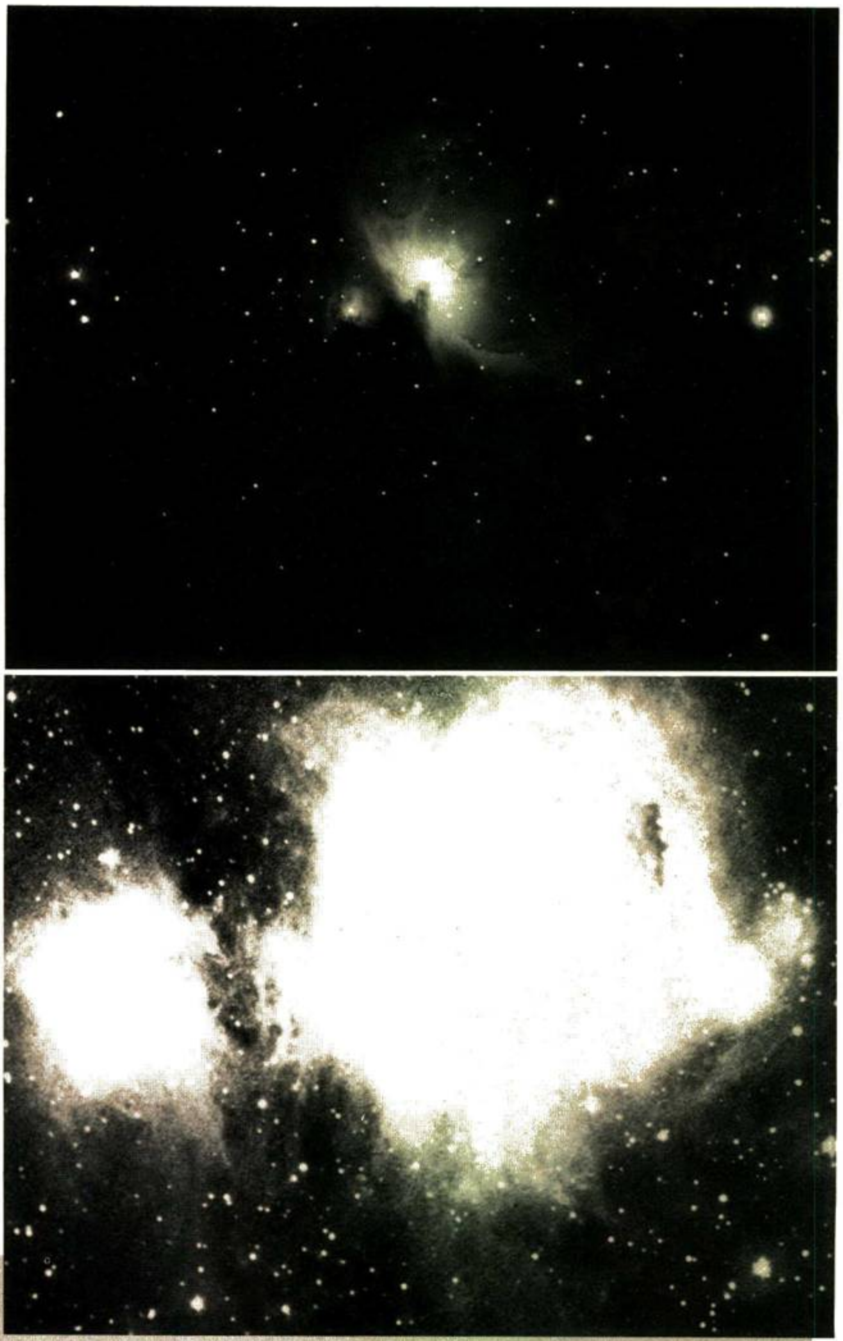


ABLAZE WITH STARS AND NEBULAE, the constellation Orion looks unfamiliar in this long-exposure photograph. Photo by Chris Schur.

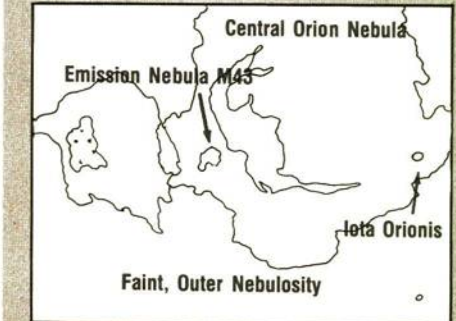

Zeta Orionis
Emission Nebula IC 434
Horsehead Nebula
Reflection Nebula NGC 2023
Emission Nebula NGC 2024

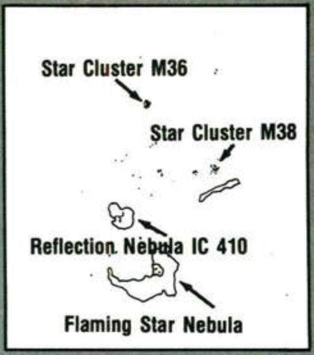
COLORS INVISIBLE TO THE EYE come alive in photographs. Jack Child's photo of the Horsehead Nebula region in Orion shows tawny yellow NGC 2024, reflection nebula NGC 2023, and the strip of light, IC 434, that lies behind the Horsehead.



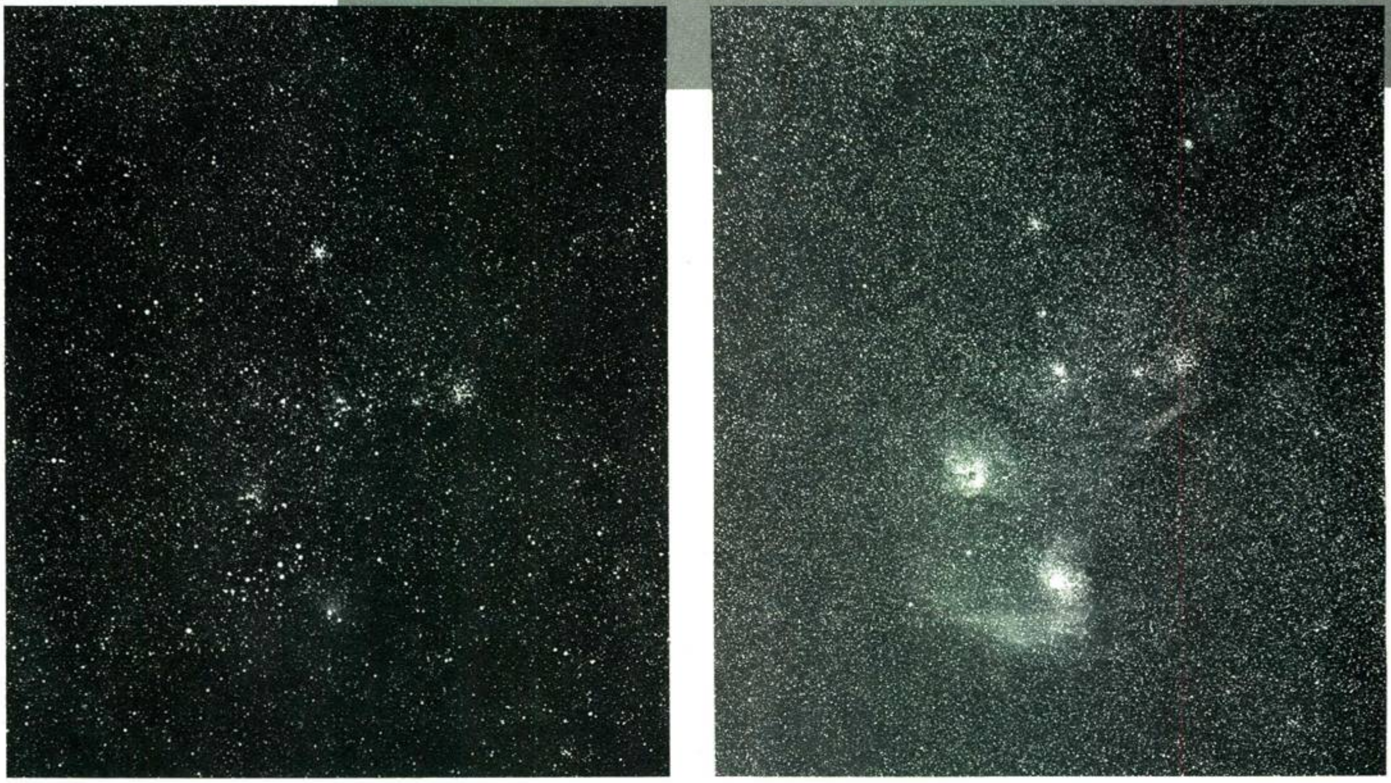


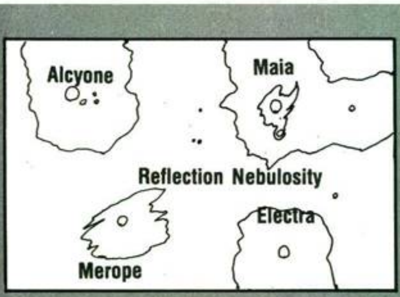
THE VISIBLE ORION NEBULA, simulated by a short-exposure photograph (top), is a roughly circular patch of greenish light 1° across. Photo by Dan Gordon. More exposure time reveals that the entire sword of Orion (above) is engulfed in nebulosity, far too faint to be observed with a telescope. Photo by Robert Reeves.


Central Orion Nebula
Emission Nebula M43
Iota Orionis
Faint, Outer Nebulosity

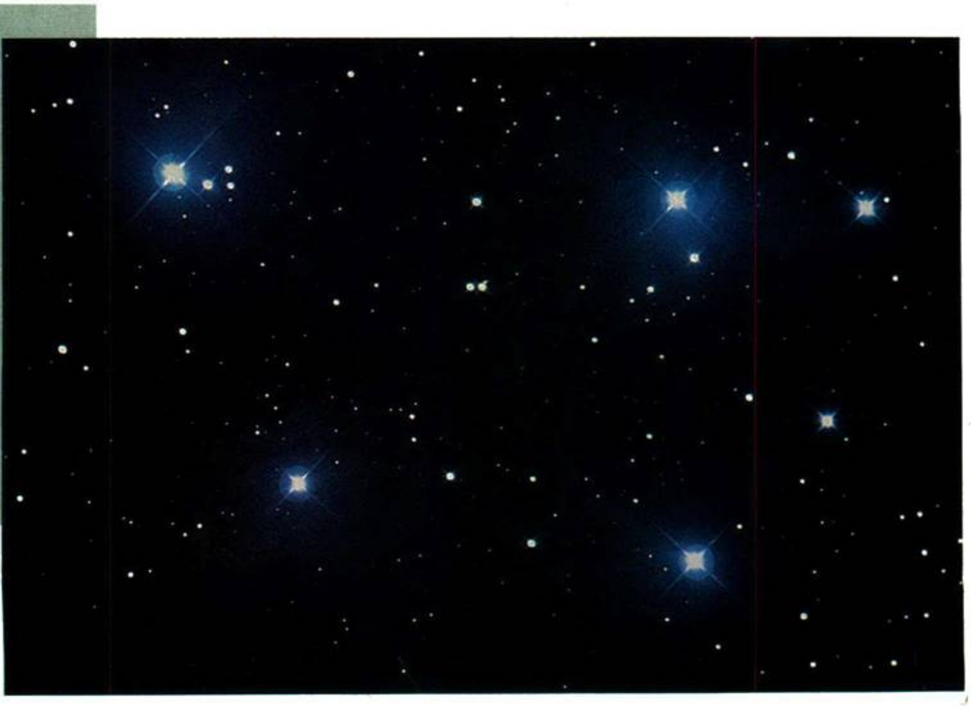

Star Cluster M36
Star Cluster M38
Reflection Nebula IC 410
Flaming Star Nebula

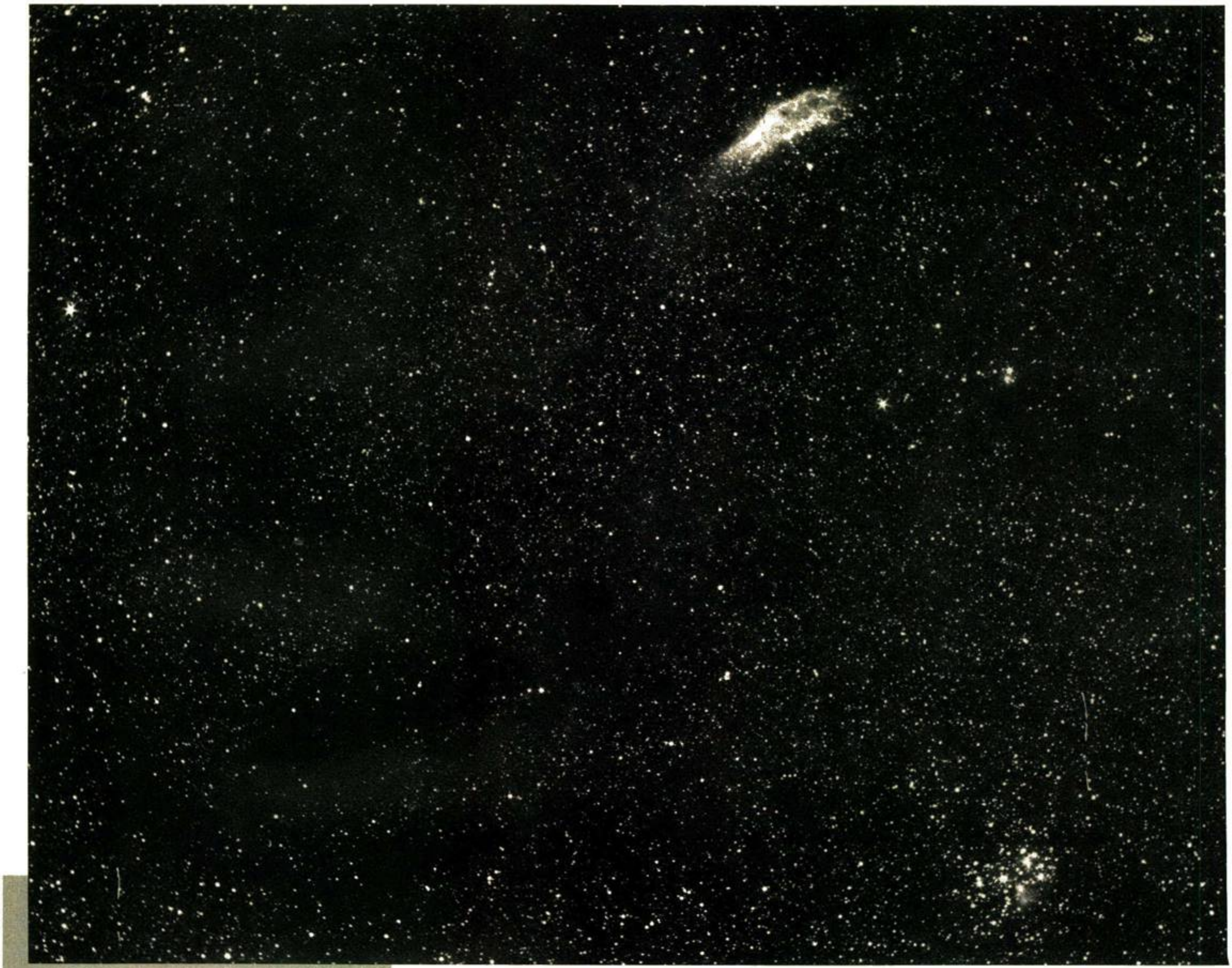
OBJECTS JUMP OUT when photographed in the right color of light. Central Auriga in blue light (below left) shows star clusters, but the same region in red light (below right) shows an extensive network of nebulosity out of the reach of observers. Photos by Ronald Royer.

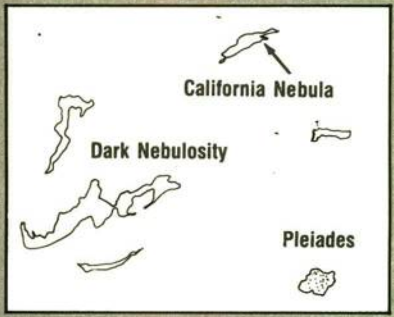



Alcyone
Maia
Reflection Nebulosity
Electra
Merope

WISPS OF BLUE GAS surround bright young stars in the Pleiades star cluster in Taurus. Visible in telescopes only with great difficulty, photography shows the Pleiades nebulosity in a 5-minute exposure. Photo by Jack Newton.







THE CALIFORNIA NEBULA in Perseus is a difficult target for telescopes, faintly visible on the best nights. Photography shows its outline and the surrounding lanes of dark nebulae. Photo by Martin C. Germano.

A color photograph of this area records a diversity in the objects' structures and colors. NGC 2024 is now a yellow nebula bisected by a curving dust band. NGC 2023, southeast of Zeta, is a blue-white spot of dust reflecting Zeta's light toward us. IC 434, the long, thin strip of red gas, frames the Horsehead Nebula.

Photography shows detail in the Pleiades star cluster, a bright object familiar to every winter stargazer. The cluster is a dipper-shaped group of blue-white beacons. A photograph shows that faint, bluish nebulosity surrounds the cluster's brightest stars, as if they were streaked with a paint brush. The nebulosity is residual dust from the formation of the cluster's stars and is difficult at best to detect with the largest amateur telescopes.

Northeast of the Pleiades is another challenging object for visual observers. The California Nebula in Perseus is a tube of gas heated so it glows by a nearby hot star. The photo above shows the nebula's faint outer extensions, its curving body variously illuminated across its surface, and an extensive network of dark lanes etched into the background stars.

Near the California Nebula in central Auriga lies a complex of nebulosity. The pair of photos on page 98 shows central Auriga in both blue and red light. The blue-light photograph shows star clusters M36 and M38 and resembles a backyard telescope view. The photograph made with red-sensitive film reveals a scattered group of faint nebulae. The largest, the Flaming Star Nebula, surrounds the star AE Aurigae, which appears as a lone star in the blue-light photo.

Enjoy observing the faint and challenging deep-sky objects scattered throughout the night sky. But also explore a second type of observing. Pull out your astronomy books and magazines and observe the wonders of the universe as they appear in photographs. You'll get a new perspective on the objects that you just can't get anywhere else. ☐

The Revolution in FAST FILM

Not only do the new fast films make astrophotography faster, but they also work for most types of astronomical objects.

The use of new fast films is spreading through the astrophotography world like wildfire. These new films will revolutionize astrophotography because they offer superb results with unprecedented short exposures.

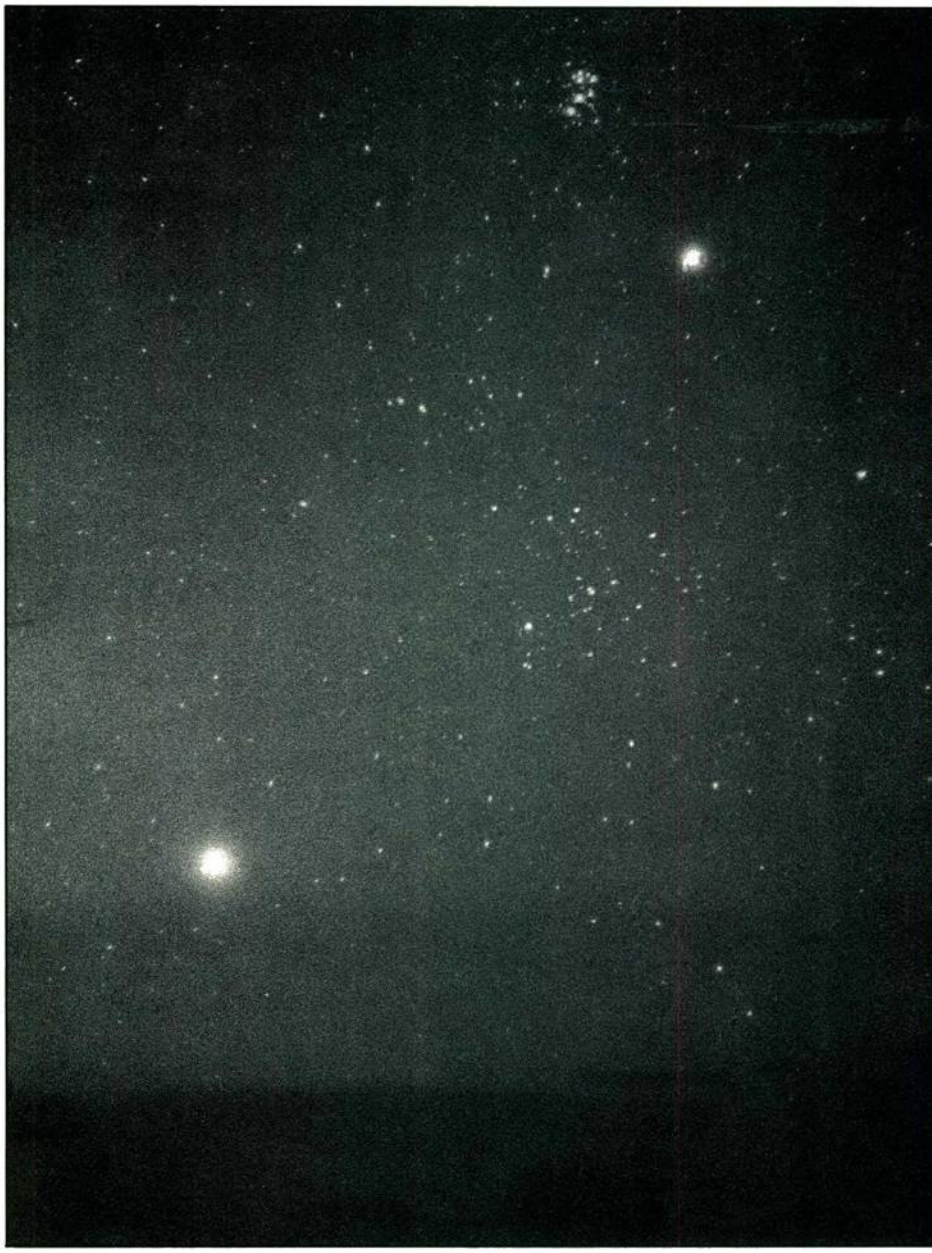
In the last two years manufacturers introduced ultrahigh-speed films like Konica's SRV-3200, Kodak's P3200, and Fuji's D1600. To understand the influence of these films, along with the slightly older 3M 1000 and Kodak Ektachrome Professional 800/1600, consider what they can do.

The new high-speed films make camera-and-tripod photography exciting. On a dark night you can record stars as faint as 10th magnitude with a 50mm lens by opening the shutter for 10 seconds. You no longer need to track a camera on the stars for a detailed constellation portrait.

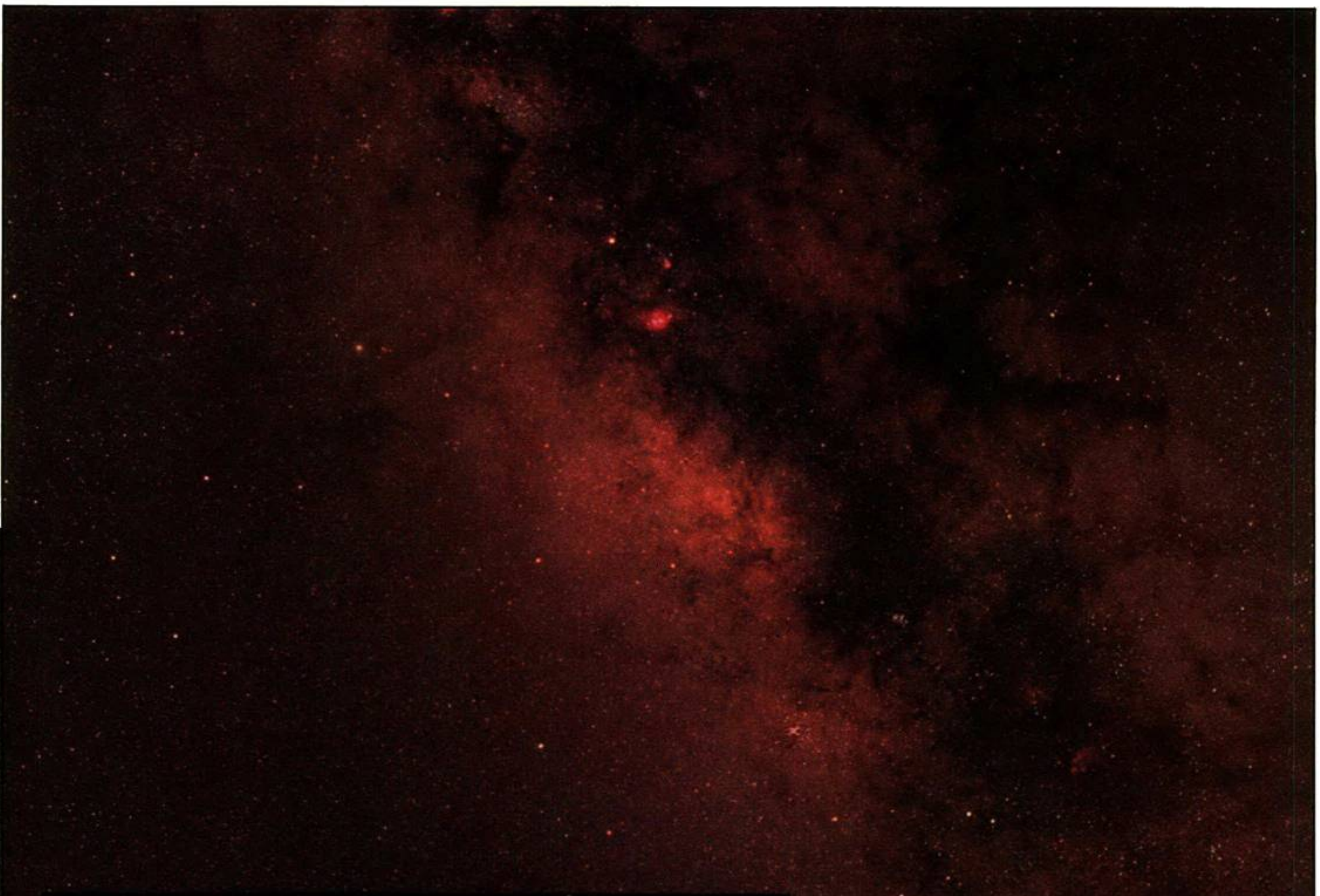
The new films may also breathe life into photographing the Moon and planets. Planets are very small, so photographing surface detail requires high magnification. This reduces their apparent brightness. And because the exposures must be so long, the planet usually moves during the exposure and its image smears on the film. The new films, however, eliminate this problem. Exposures can be as short as 1/15 or 1/30 second: the same exposure you use on a cloudy day at the beach.

With guided astrophotography, fast films shorten exposure times. They let you take more photos per night, and you only have to guide for a few minutes at a crack. Photographing the motion of an asteroid is now reduced to two 2-minute exposures taken a few days apart.

If you've always been intimidated by astrophotography, try a roll of high-speed film with your camera and tripod. When the pictures come back, you'll be astounded at the direction astrophotography is heading. ☐

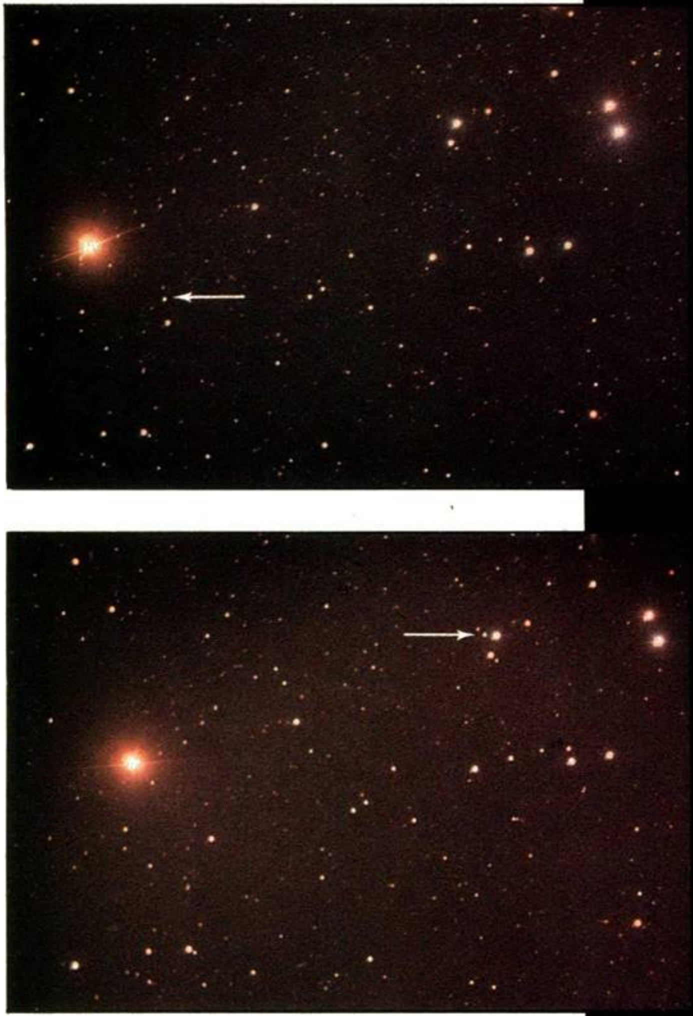


A 10-SECOND EXPOSURE on P3200 film push-processed to ISO 6400 shows stars as faint as 10th magnitude. Jupiter lies between the Hyades and Pleiades clusters at upper right and Venus is at lower left. Photo by Richard Berry with a 50mm f/1.4 lens.



A GUIDED PHOTOGRAPH of the summer Milky Way shows deep-sky objects by the dozens. Jason Adamik piggybacked a Pentax 6x7cm camera and a 105mm f/4 lens on his clock-driven telescope. He exposed Konica 3200 film for 8 minutes.

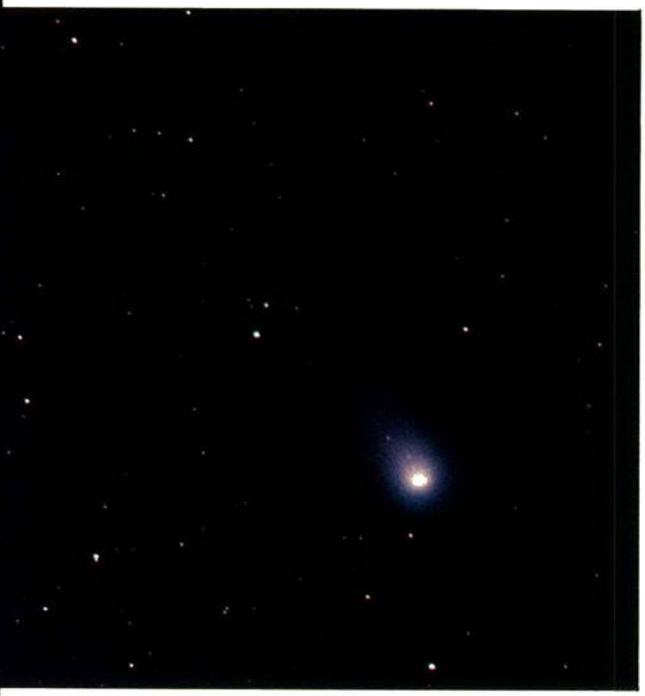
A CLOSE-UP of the Hercules Cluster and spiral galaxy NGC 6207 demonstrates how fast film can record small details over a long exposure. Jeffrey Jones used an 8-inch f/10 SCT, hypersensitized Konica 3200 film, and a 30-minute exposure.



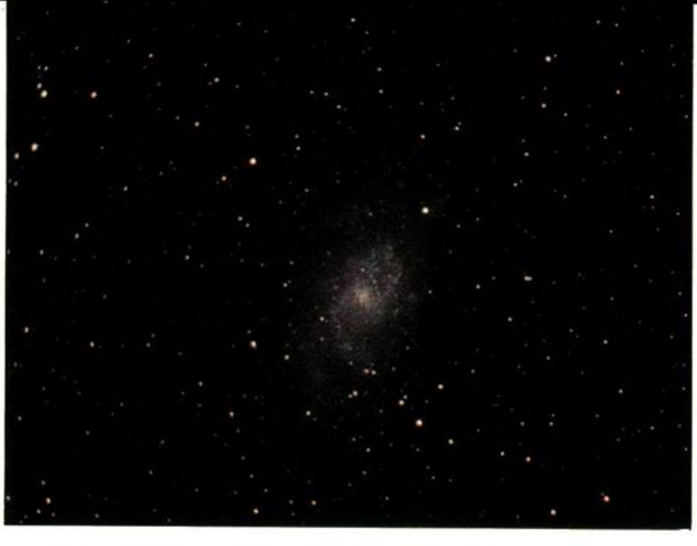
ASTEROID 44 NYSA passes through the Hyades cluster in this pair of Konica 3200 exposures. The film's high speed makes it possible to record motions of faint asteroids in as little as two minutes. Photos by Steven Simmerman with a 5.5-inch f/3.6 Schmidt-Newtonian telescope.

LUNAR ECLIPSE AT DAWN on April 26, 1986, is visible in an exposure of only 6 seconds. Jerry Schad used an 85mm f/4 lens and Ektachrome P800/1600 film developed at ISO 800.

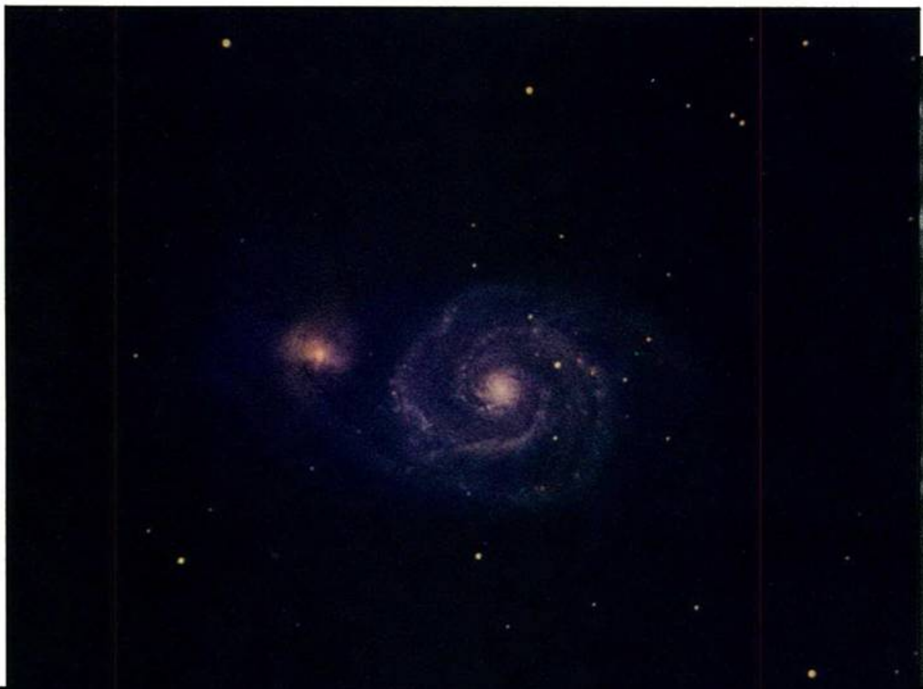
THE MOON AND VENUS lie less than 1° apart in this 2-second exposure on Fujichrome 1600 film. Martin Hale photographed the pair with his 6-inch SCT at prime focus.



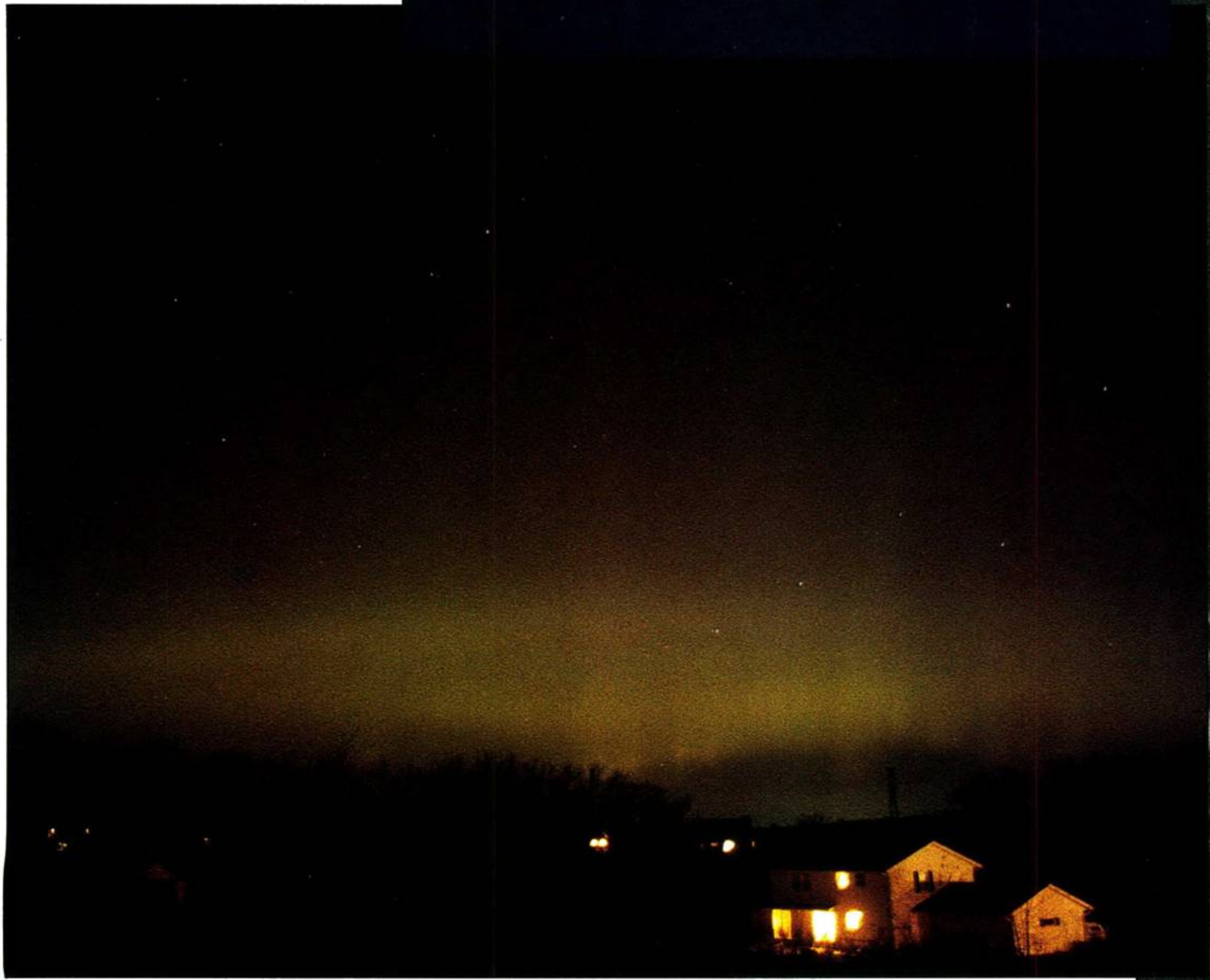
COMET LILLER 1988a displays a bright bluish coma and a faint, lavender tail in this 6-minute exposure on hypered Konica 3200 film. Before fast films, comet photographers needed much longer exposures to record the subtle objects. Photo by Jeffrey L. Jones with an 8-inch f/10 SCT.



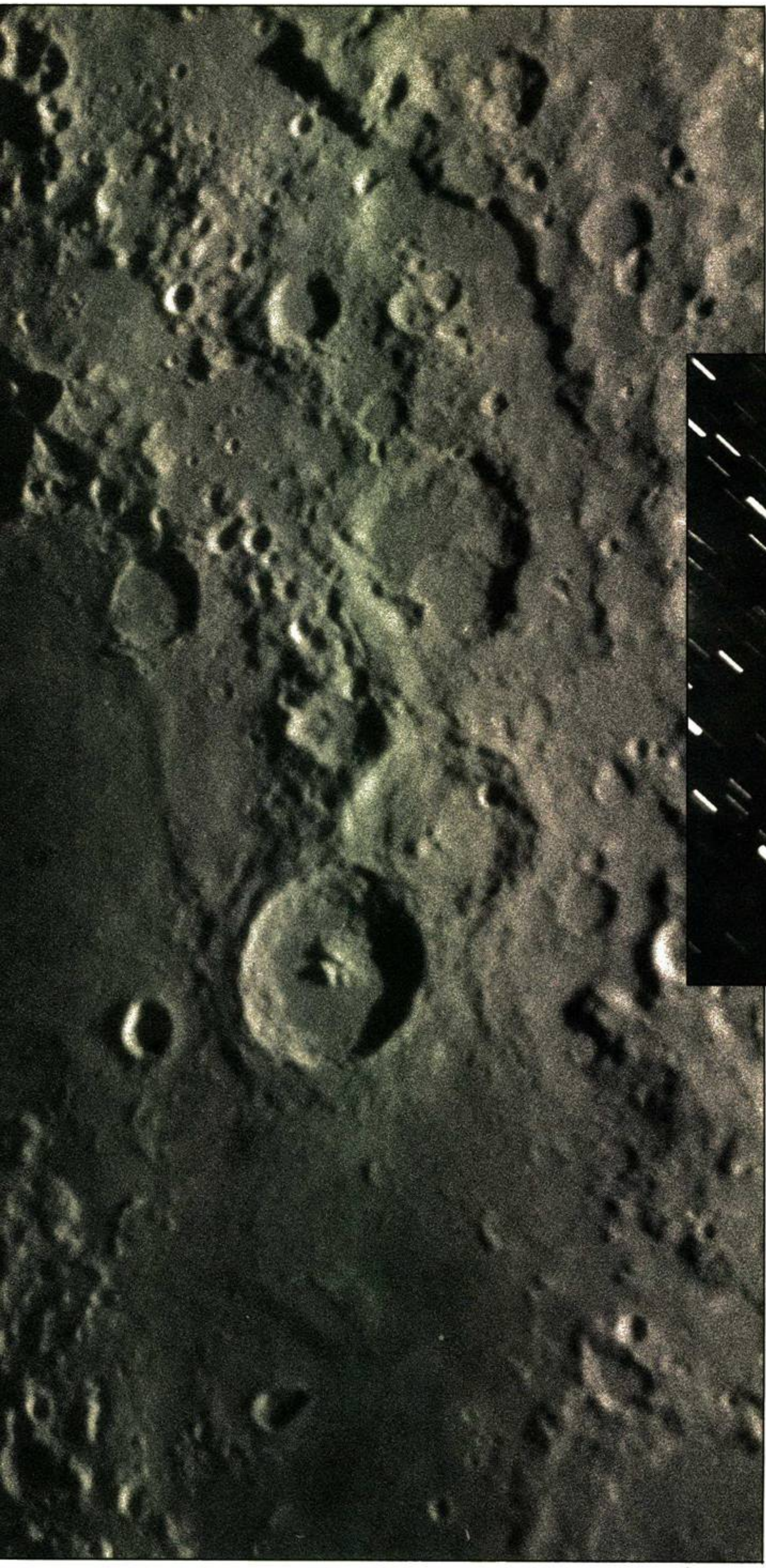
SPIRAL ARMS IN M33, a faint, low surface brightness galaxy, were recorded in this 30-minute exposure on hypered Konica 3200 film. Photo by Scott McGurk with a 6-inch f/3.6 Schmidt-Newtonian.



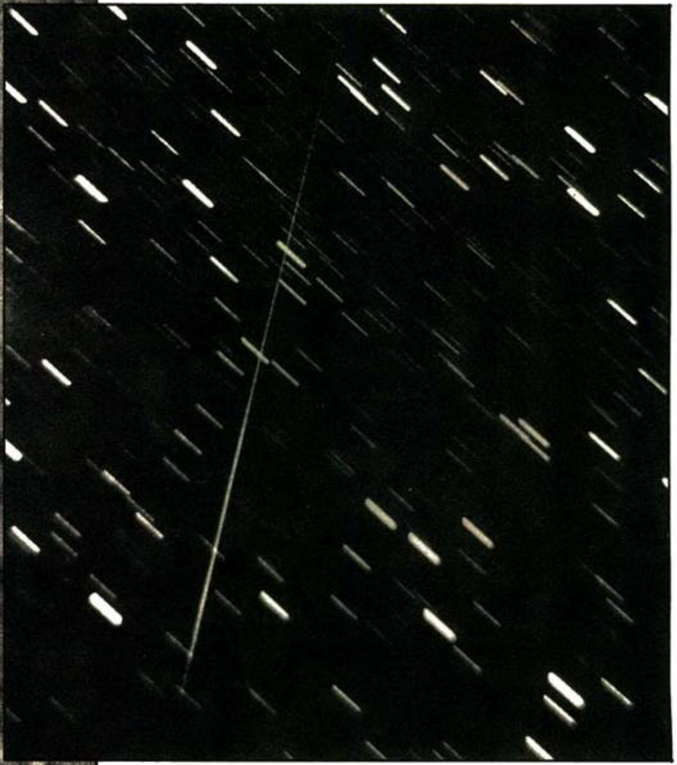
THE WHIRLPOOL GALAXY in Canes Venatici shows minute structural detail in this 70-minute exposure on hypered Konica 1600 film. Kim Zussman used an 11-inch f/10 SCT.



A GREENISH AURORA glows eerily as the Big Dipper rises in this 3M 1000 exposure. Jim Bailey used a 50mm lens, set his camera on a tripod, and exposed for 5 minutes.



A HAND-HELD MOON PHOTO shows craters Theophilus, Cyrillus, and Catharina adjacent to Mare Nectaris. Richard Berry held his camera and a 50mm lens up to a 7.4mm eyepiece mounted in a 10-inch f/6 Newtonian. He snapped a 1/30-second exposure on P3200 film push-processed at ISO 6400.



A PERSEID METEOR ZIPS BY in this exposure showing the trailed stars of Cassiopeia. Lee Coombs used a 50mm f/2 lens and 3M 1000 film.

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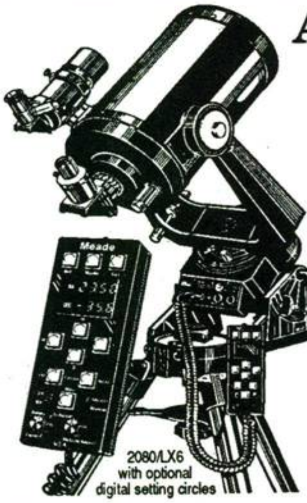

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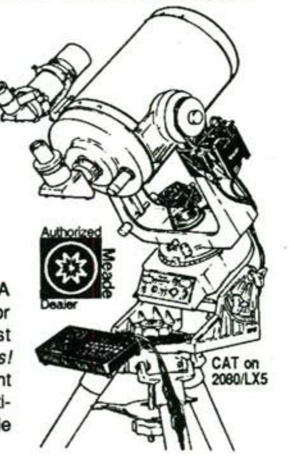

CAT on
2080/LX5

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The $3800 Meade 2080/LX5 is still only $1595!

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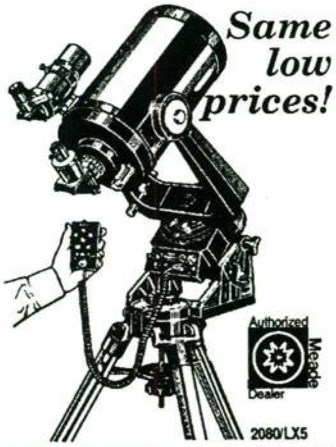

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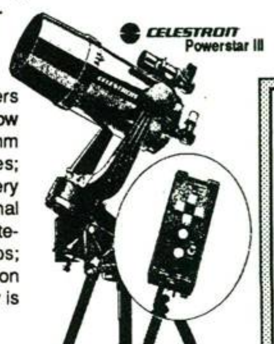

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The Astrophotographer's Gadget Box

Handy gadgets can make guiding, tracking, accurately exposing film, and copying slides easier.

Astrophotography should be a joy, not a tribulation. And yet too often our enthusiasm is dampened by the unsatisfactory results caused by shutter vibration or guiding errors. In reality these mishaps don't have to occur. In fact, as proven by astrophotographers who have "been there," many of the insoluble problems in astrophotography can be easily resolved with spare parts and a little ingenuity.

REPHOTOGRAPH YOUR ASTROPHOTOS

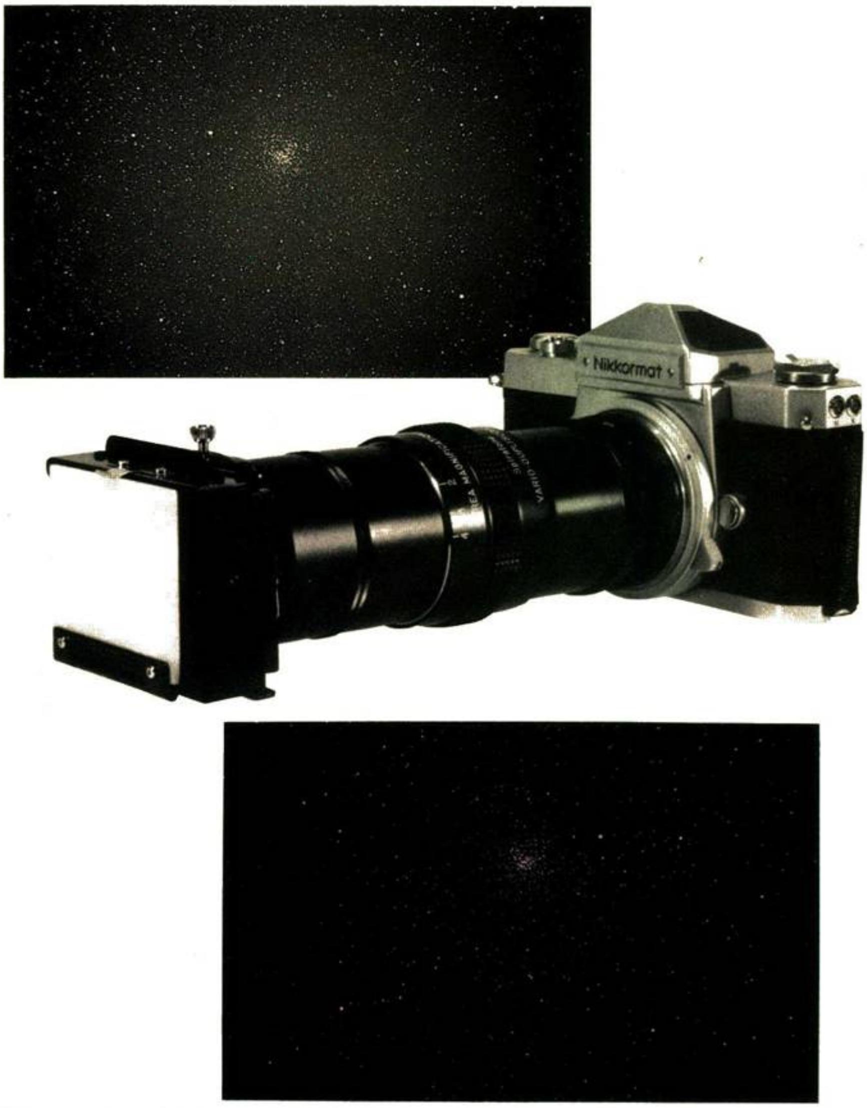
Do your slides lack spectacular color and contrast? Is light pollution washing out your sky backgrounds? Maybe it's time to enhance your slides by rephotographing them. No, I don't mean packing up the astrophoto gear and preparing for another long night of guiding. You can improve your astroslides simply by rephotographing them with a slide duplicator in the comfort of your own home.

Slide duplicators can be attached to any 35mm single-lens reflex camera body (sans lens) by using a standard T-mount. The duplicator is prefocused so all you have to do is frame your slide or negative and provide the correct exposure.

Slide duplicators, aside from allowing you to make slide copies, let you compensate for exposure errors and low-contrast features in the original slide. Good results can be obtained by using a daylight, fine-grain film like Ektachrome 100 and aiming the duplicator near (not at) the Sun. With an automatic camera the exposure will be very close to the setting computed by the camera's light meter.

Dark, underexposed slides can be brightened by bracketing two stops

Slide Duplicator



Improve your astroslides by copying them in a slide duplicator. The photo of M37 (top) was taken with 3M 1000 film. The duplicate above was copied onto Ektachrome 200 film with a magenta filter.

longer. For example, if your meter reads 1/60 second, take photos at 1/30 and 1/15 second. Bright slides with excessive fogging can be darkened somewhat by bracketing two stops shorter than the true meter reading. So if your meter reads 1/60 second, take photos at 1/125 and 1/250 second. Record your data so that when the film is processed, you'll know which exposure turned out best and you can repeat this without wasting film.

Brightening slides brings out detail nearly invisible in the original slide. Faint outer regions around nebulae and galaxies and delicate wisps in comet tails are beautifully enhanced by slide duplication. There may be a slight loss in sharpness and stars will lose some color in the process, but this is a small price to pay for the gain in detail and contrast.

Another way of improving contrast is to use color filters with a slide duplicator. By placing the appropriate color filter in front of the duplicator's diffuser, you can filter out objectionable sky background colors in the original slide and create an aesthetic, dark sky. For example, the greenish hue typical of 3M 1000 slide film exposed in a slightly light-polluted sky can be filtered out with a magenta filter.

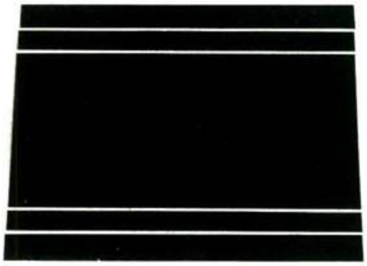
These filters are available in most camera stores that carry darkroom supplies. Color filters can strongly enhance the reds of a nebula or the blues in a galaxy and thus increase the contrast of the object with the sky background. The same magenta filter really brings out the color and contrast of the North America, Rosette, and Horsehead nebulae. For additional red enhancement of emission nebulae, try using a 150-watt incandescent bulb as a light source with the duplicator about 6 inches away. Color filter duplicating is an area where trial and error and experimentation pay off.

Slide duplicators can also make slides from black-and-white negatives. Place a negative (mounted in a slide mount) in the duplicator and photograph it with a high-contrast black-and-white negative film (Technical Pan 2415). The result will be a beautiful high-contrast positive ready for projection as a black-and-white slide.

Color negatives can also be produced in a slide duplicator. Just load your camera with print film (Kodak VRG 100 works very well) and rephotograph your slides as you would using 100 ISO slide film. In this way you produce a set of internegatives of your best color slides that can be made into spectacular prints and enlargements. Try getting them developed at a one-hour photo lab. If you make the the lab's staff understand what you want, you may be pleased with the results. — *Hal Jandorf*

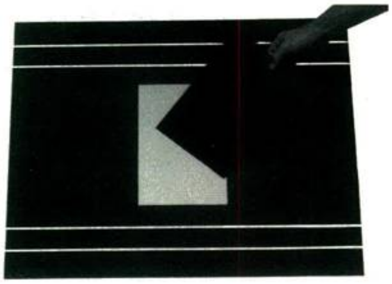
Manual Shutter

A



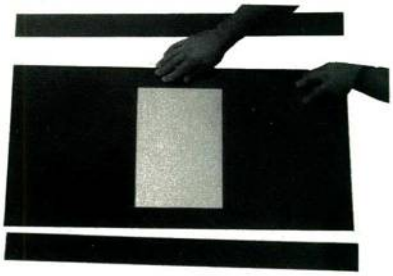
Cut out sections for your shutter from an oversized piece of black matte board. The dimensions of the shutter depend on the size of your telescope (see text).

B



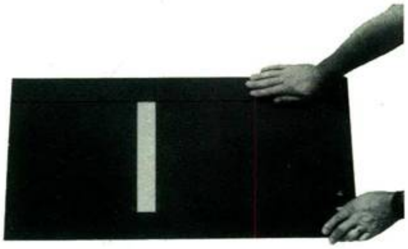
Cut out the slit window and set it aside; this will be your adjustable slit cover.

C



Glue down the slit tracks, making sure the slit cover fits snugly and slides smoothly between the tracks. Then glue down overlapping tracks.

D



The slit cover should slide up and down in its tracks but not slip out of position once it's set. This gives you an adjustable aperture opening.

A VIBRATION-FREE CAMERA SHUTTER

With just a minimum of effort and skill, you can construct a hand-held slit to go in front of the telescope's aperture that will give you a short, vibration-free exposure.

The shutter is basically a vertically shaped device with a window or slit in the middle, and the opening can be varied to allow for different-speed exposures. You will need an oversized piece of heavy, flat, black cardboard (such as matte board) to cut the pieces of the shutter from. In addition you will need glue, a yardstick, a utility knife, and a few heavy books.

The shutter's dimensions depend on the telescope's aperture. The length of the main piece should be six times the aperture; the width should be three times the aperture. Cut this section from the of matte board and set it aside. Next, cut out the slit guides. These consist of four narrow sections of cardboard. The first two guide pieces are as long as the main piece of cardboard, but each is only half the telescope's aperture wide. The second two guide pieces are the same length but are a half-inch wider.

The slit opening is cut from the center of the main piece. The width of the slit should be twice the aperture and the length should equal the aperture size. Save the piece you remove; this will become your slit cover.

Glue the narrow guides along the edges of the main piece with the slit cover placed snugly between the guides. The slit cover should be adjustable but not loose. Next glue the wider guides on top of the narrow guides. Allow this assembly to dry under a few heavy books.

Floating Reticle

A

To make a floating reticle, you need an old eyepiece, a pencil eraser, and a small-gauge sewing machine needle.

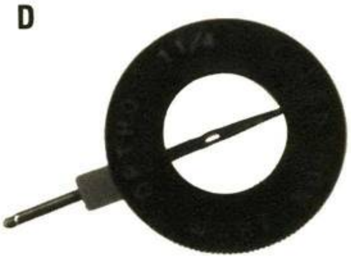
B

Drill a hole at the focal plane of the eyepiece. The hole should be slightly smaller than the diameter of the eraser. Then push the sewing needle through the eraser.

C

Insert the sewing needle point-first into the eyepiece hole.

D



The needle's thread guide becomes a star guide in the eyepiece. It can be adjusted in or out and the eyepiece rotated to locate a suitable guide star.

To use, hold the shutter vertically in front of the telescope's aperture so one end of the shutter covers the aperture while the slit opening and the opposite end of the shutter lie above the aperture. Lock open the camera shutter, let vibrations die out, and move the shutter down at a steady rate so the open slit passes across the aperture. When the opposite end of the card covers the telescope aperture, close the camera's shutter and advance the film for the next exposure.

Exposure time depends on the size of the slit opening and how fast you pass the shutter across the aperture. With the slit fully open, the exposure will be about one quarter of the time it takes to pass the card over the telescope's aperture. If this movement takes one second, then the exposure is 1/4 second. Reducing the slit to half open gives a 1/8-second exposure; one third its aperture gives 1/12 second.

For solar eclipse or lunar and planetary exposures with fast films, try dropping the shutter vertically, but be sure to catch it before it falls too far! Exposures as short as 1/60 second should be possible with the slit about one quarter open. — *P. P. Coleman*

THE FLOATING RETICLE

Diffuse objects like comets, nebulae, and galaxies are difficult to track without a definite point to fix upon. And it can be a tedious affair to reset your finder or guidescope on a suitable guide star. A better idea is to place a distinct reference device in the guiding eyepiece — a floating reticle — that can be easily adjusted to track most stars in the field of view.

All you need to make a floating reticle is an old eyepiece you don't mind drilling into, an unmarred pencil eraser, a drill bit slightly smaller than the eraser, a drill, and a sewing machine needle — the smallest you can find. My needle was a size nine. Bear in mind that the floating reticle can be attached to any eyepiece that rotates or can be made to rotate in its holder. Therefore, it is not only useful in finders but in the telescope itself.

Drill the hole at the focal plane of the eyepiece. (The focal plane can be determined by looking through the eyepiece while probing up the open end of the eyepiece with the needle and noting where the needle's point comes to focus.) Push the needle through the eraser and then insert the whole assembly point-first into the hole. It should fit very snugly. If not, a drop of Super Glue will hold it.

As you look through the eyepiece, the needle point should be in focus. Turn the needle point until the hole in the point is visible. The idea is to center a star or comet nucleus in the telescope or camera field, and then look through the finder or guidescope for a suitable guide star. You "trap" that star in the hole of the needle by rotating the eyepiece and pushing or pulling the needle through the eraser.

Don't expect to have room to fully rotate the eyepiece in finders or guidescopes. It isn't necessary. All you need is 180° to cover the entire field of view. In telescopes the eyepiece will fit into the focuser only as far as the needle, so take care that you have enough focusing distance to allow for the difference. — *Greg Beavers*

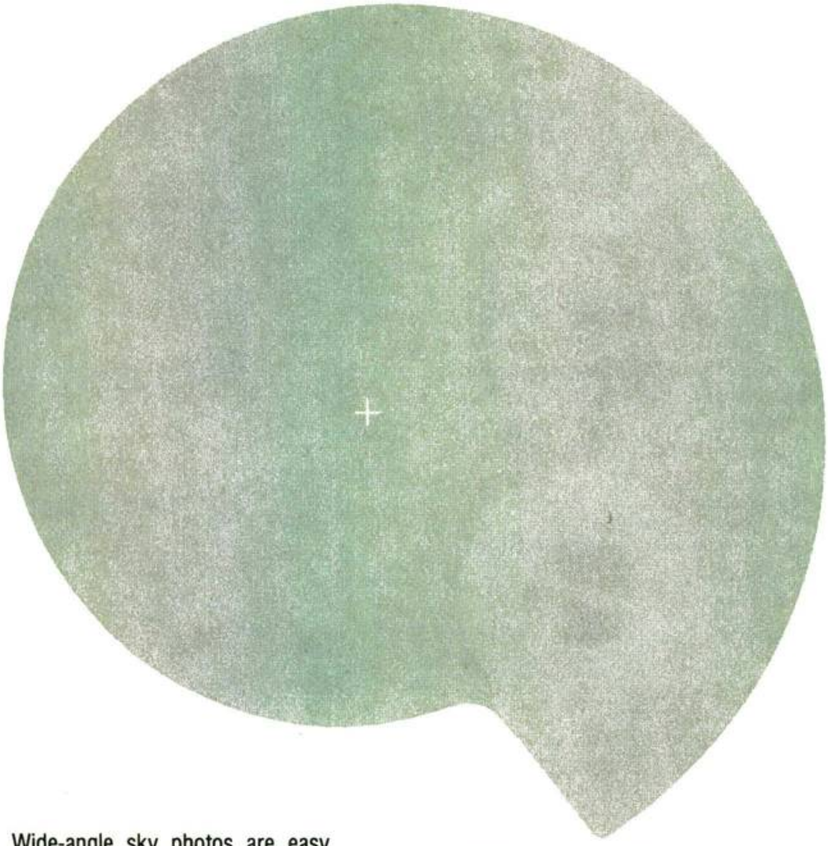
A STURDY CAMERA PLATFORM

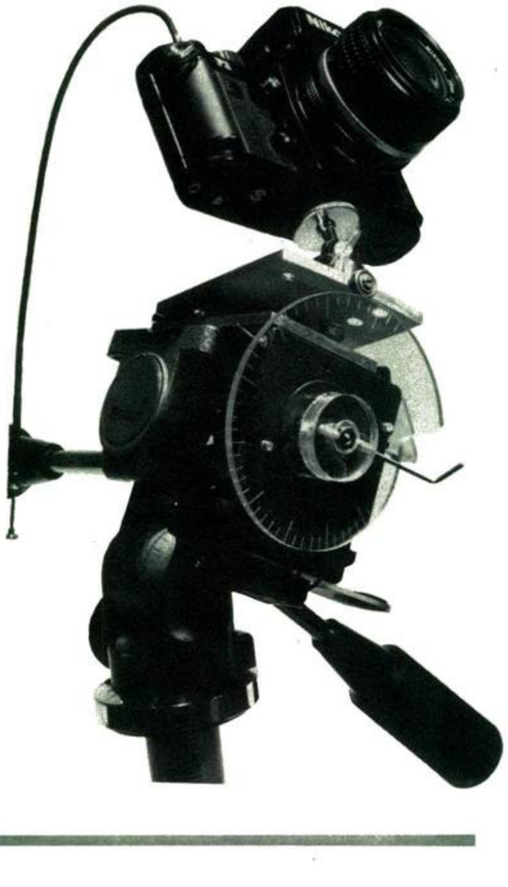
To prepare for Comet Halley, I needed a camera drive system that was simple in design, compact, accurate, and able to operate in subzero temperatures. From these criteria, I built a camera platform without using special techniques. Most of the materials add up to only about $10. The two main platforms can be made of whatever you can find that's stiff — scrap metal, aluminum, or wood.

Gravity is the power source for this camera drive system; the clock acts only as an escapement to control the rate of fall. The cam compensates for both sidereal motion and sine error, the latter of which is a problem with many "barn door" designs.

The clock is an impulse-wind mechanism, which means it winds itself approximately every seven minutes. Thus, there is not a steady drain

Camera Platform





Wide-angle sky photos are easy with a sturdy camera platform (right). This platform was constructed with a clock mechanism, two hinges, and scrap material. The outline of the cam (above) is the actual size of the cam in the photograph; use it as a template for making your own cam.

Clock Mechanism Suppliers

H & R Corporation
401 East Erie Avenue
Philadelphia, PA 19134

Jerryco Inc.
601 Linden Place
Evanston, IL 60202

on the battery and vibration is kept to a minimum because no one has to crank a drive bolt or touch the drive in any way while making an exposure. If the battery voltage is low because of freezing temperatures, the rewind motor may operate slower but the timekeeping is not affected.

Such a clock mechanism is available from surplus dealers. Other clock escapements can be used if you solder the clutch that allows the hands of the clock to be set.

The cam, which I constructed from Lexan, a thermoplastic similar to Plexiglas (and available from various plastic distributors and fabricators), is simple to lay out and cut on the band saw. Sanding to the layout line with a disk sander is all the accuracy necessary.

The formula for producing a cam for any length platform leaf of the hinge is $S = 1.5 + [R \text{ x sine } (\theta \text{ x } 0.04150461)]$, where S is the cam radius, θ is the angle on the cam, and R is the radius from the center of the hinge pin to the contact point of the bearing on the cam. The 1.5-inch dimension is simply the distance from the center of the cam to the bearing contact at its lowest travel point; the other value is the rate the sky moves per hour divided by 360°.

When I made my cam, I took a point every 10° and connected the points with a French curve. Then I carefully sanded or filed close to the layout line in one smooth curve.

The lower platform leaf is mounted to the top of the clock and has the standard ¼-20 tapped hole to mount on a tripod. The upper platform leaf has a bearing that rides on the cam and a row of holes to accommodate a universal ball head for cameras and lenses of different weights. The ball head is mounted so the weight of the camera keeps the bearing riding on the cam but not with such force that the cam pushes the clock into a gallop. The short leaf eliminated problems of flexure with heavy cameras. As a result, the platform can accommodate my Nikkormat with its 220mm lens pointed anywhere in the sky.

A small platform mounted at the bottom of the clock with a sticky pad can hold a watch for timing exposures. A battery box on the bottom powers an LED, which illuminates the watch. The switch could be eliminated if you don't mind taking out the batteries to turn the diode off.

For $10 and a little work, this drive has rewarded me with many evenings of satisfying, trouble-free astrophotos. For $10 and a little work, that ain't bad. — *Gerard L. Cutting*

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FABIAN LUCID
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STS 51G
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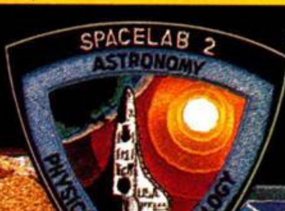
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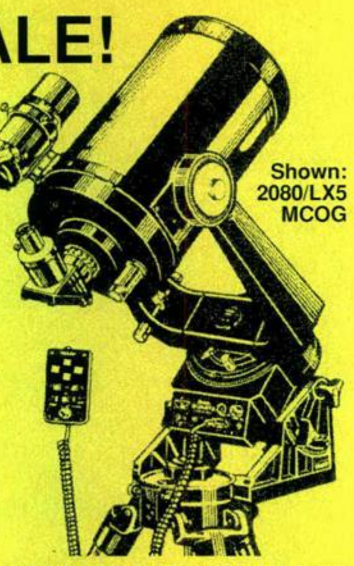

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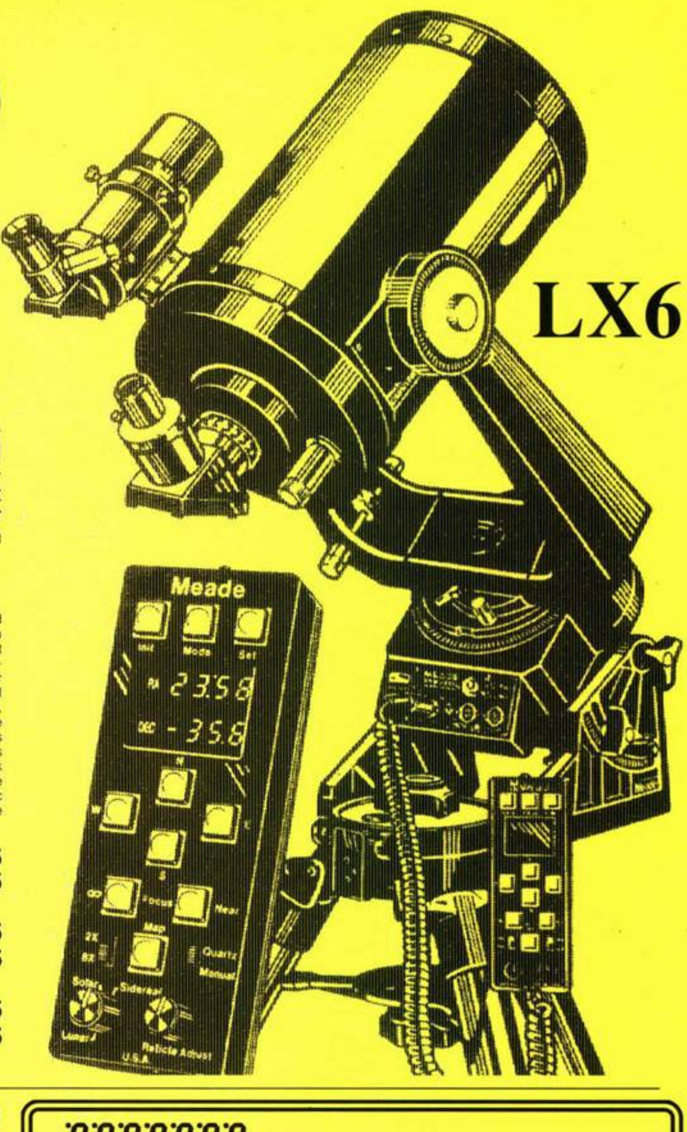

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2080/LX6	(List: $4,400)	**$1,887.95**
2120/LX6	(List: $6,400)	**$2,477.95**

Optional Digital Readout System:

Mod. 9068, *for* 2080/LX6	(List: $ 590)	**$ 337.95**
Mod. 9070, *for* 2120/LX6	(List: $ 590)	**$ 337.95**

Package: Telescope *and* Optional Digital Readout System, together:

2080/LX6 *with* Mod. 9068	(List: $4,990)	**$2,187.95**
2120/LX6 *with* Mod. 9070	(List: $6,990)	**$2,777.95**

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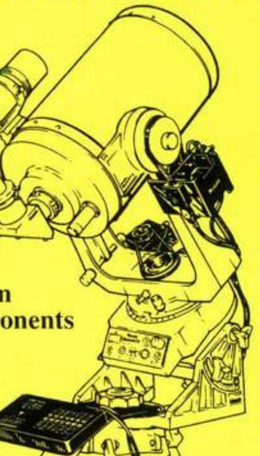
Meade's Computer-Aided Telescope System



CAT
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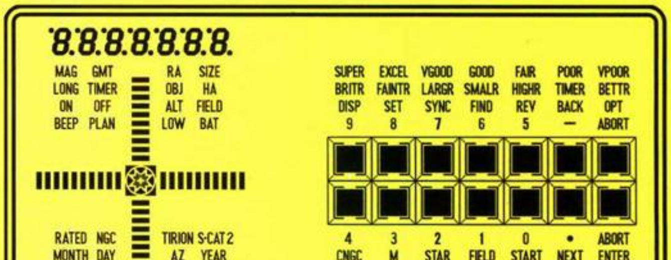
Components

Meade's **C**omputer-**A**ided **T**elescope (the "CAT") system has most of the advantages of a computer-controlled telescope at only a fraction of the cost. Consisting of a specially-designed, high-speed, extremely powerful computer, along with a pair of high-resolution incremental shaft encoders and their associated mounting hardware, drive components and cabling (*see general arrangement drawing at left, and panel layout drawing at right*), the CAT can readily and quickly direct you to any of the thousands of celestial objects whose coordinates and other descriptive information are permanently stored in its 1Mb plug-in EPROM database, ***including all of the planets***, as well as to any other celestial object of known coordinates (comets, asteroids, quasars, super-novae, etc.). The computer is loaded with extra features and functionality as the panel legends, at right, indicate.

For the computer-literate, there is also a version of the CAT available with an RS-232C port (the "CAT-COM") for connection to a "PC" compatible personal computer. CAT-COM includes four "demonstration" software subroutines, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software is supplied on a 5.25" 360Kby diskette, with backup source-code listings in the instruction manual.

The CAT is available for most fork-mounted Schmidt-Cassegrain telescopes, but has been ***electronically integrated*** with the new LX6 series, so that the encoders and the CAT computer plug directly into the drive-base. Consequently, during our introduction of the LX6 series telescopes, we are offering extra savings on packages consisting of an LX6 telescope and one or the other of the CAT systems.



Optional Computer-Aided Telescope (CAT) System:

CAT *for* 2080 or 2120/LX6	(List: $1,990)	**$1,187.95**
CAT-COM *for* 2080 or 2120/LX6	(List: $2,290)	**$1,362.95**

Package: Telescope *and* Optional CAT System, together:

2080/LX6 *with* CAT	(List: $6,390)	**$2,987.95**
2080/LX6 *with* CAT-COM	(List: $6,690)	**$3,137.95**
2120/LX6 *with* CAT	(List: $8,390)	**$3,577.95**
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YELLOW DUST CLOUDS ON MARS

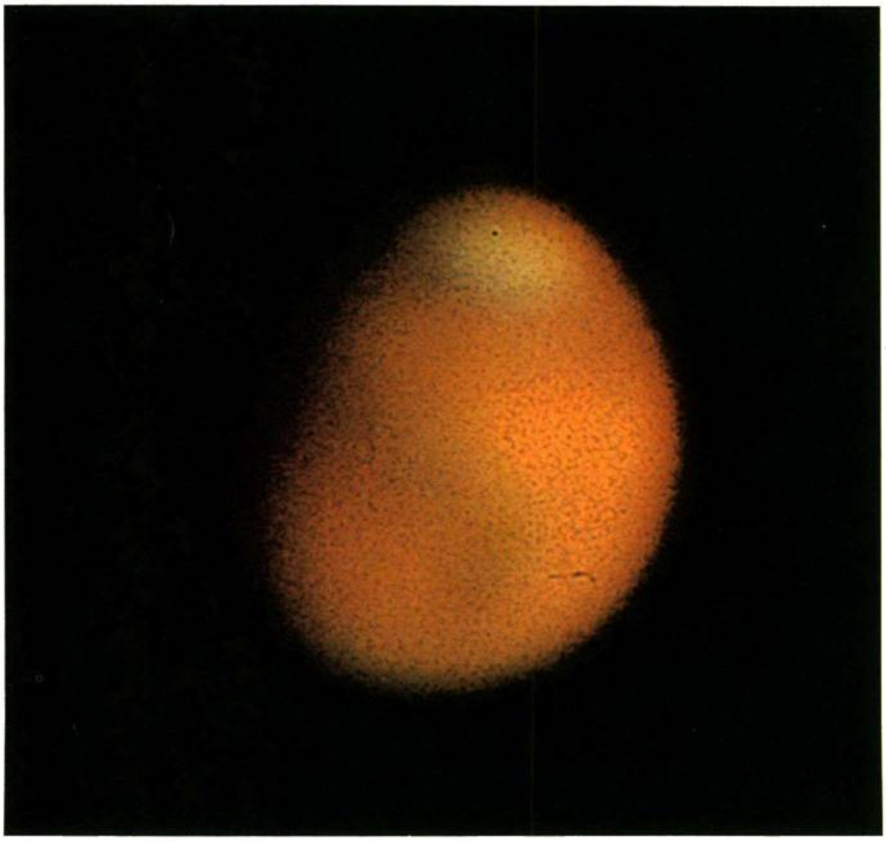
As Mars increased in size toward its maximum in September, the planet continued to provide an active show for amateur astronomers. During June and July dozens of observers reported yellow dust clouds at various places on the planet's surface.

By June 19 the dust covered at least 90° of aerographic longitude, according to Jeff Beish and Donald C. Parker, Mars Recorders for the Association of Lunar and Planetary Observers. Beish said that "according to Japanese astronomers, by June 17 the following edge of the dust cloud, visible at high magnifications, was located over western Noachis at approximately 350° longitude."

On June 19, Isao Miyazaki, Masatsugu Minami, and nine other members of the Oriental Astronomical Association's Mars Section reported no further development in the Noachis cloud but found a yellow cloud in the region of Argyre I.

After June 20 the dust storm subsided. However, Lowell Observatory's Leonard Martin reported an increase in the brightness of the Martian south polar cap. Other observers, including Beish and Parker, observed a yellowish haze covering the polar cap until mid-July.

Unusual variations in the albedo of Mars followed the dust storms. On June 23, Miyazaki reported that Hellespontus, which had been obscured during the storm, was dark and conspicuous. By June 27, Mare Hadriacum was faintly visible, and by mid-July it was dark and easily seen. Also in July the region known as Sabaeus Sinus enlarged to the southeast and "attached" itself to Mare Serpentis, which gave this region an appearance not seen for over a decade.



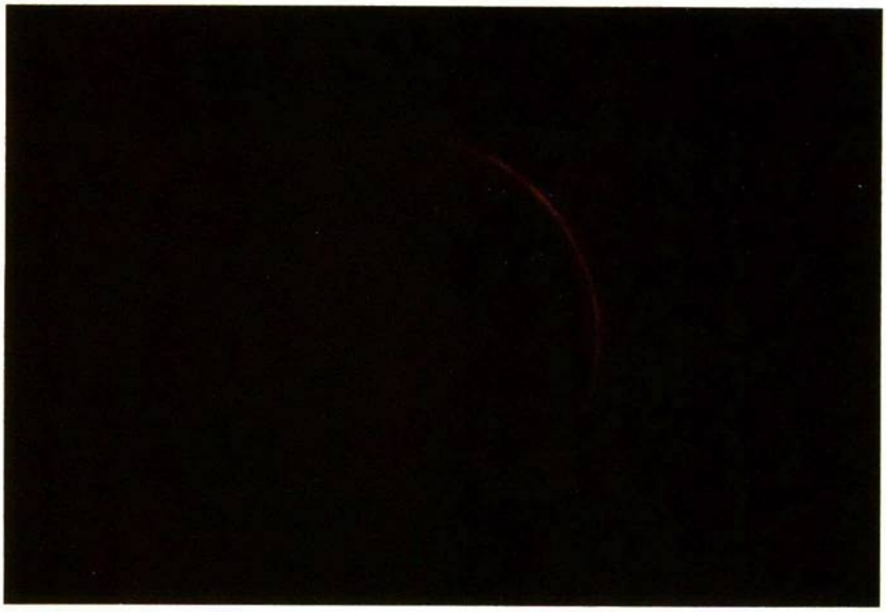
POLAR CAP AND DUSKY MARKINGS show on the surface of Mars (above) in this photo made on June 15, 1988. Donald C. Parker used a 12.5-inch reflector at f/165. On July 12, Parker again photographed Mars (right, top), then larger and brighter than it appeared in June. Parker used the same instrument with Tech Pan film and a 3.5-second exposure. Isao Miyazaki's sketch (right), made with an 8-inch f/7.9 reflector at 395x, shows Mars with a dark rift in its polar cap on June 29. South is at top in each view.

YOUNG MOON SPOTTED

One of the summer's most unusual observing opportunities came in July when stargazers had the chance to see an exceptionally young Moon. On July 14 a tiny crescent Moon just twenty-five hours old was visible low in the west just after sunset. The event was observed and photographed by many amateur astronomers, and the U.S. Naval Observatory sponsored an observing program to see who would see the young Moon from various locations.

From Sallisaw, Oklahoma, Bob Moody spotted the young Moon at 8:55 p.m. CDT on July 14. Moody spotted the Moon with the naked eye despite the fact that the sky was somewhat hazy and an anvil-shaped cloud top lay just 2° below the Moon. He later sketched the young Moon with a 6-inch f/8 reflector at 45x and 90x and identified the craters Gauss and Humboldt near the Moon's edge.

From Belgium, Wisconsin, Richard Berry searched for the young Moon in a sky containing "hazy cloud bands to an

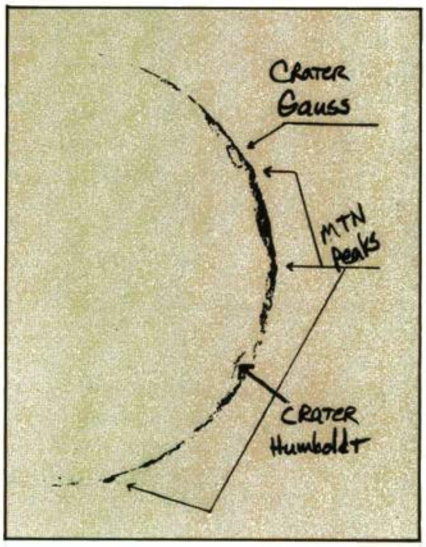


JUST TWENTY-FIVE HOURS OLD, the Moon is a sliver of light in this photograph made at 9 p.m. CDT on July 14, 1988. William W. Sager photographed the young Moon from College Station, Texas, with a 3.25-inch f/6 refractor, Ektachrome 200 film, and a 1/2-second exposure.

altitude of 10° and mare's-tail clouds over the rest of the sky." Berry didn't see the Moon with eyes alone, but 11x80 binoculars showed a "120° arc of crescent Moon at an altitude of about 3°. I saw the Moon for about three minutes before it set into a long band of clouds at an elevation of 2°."

Robert Burnham observed the young Moon from the northern edge of Milwaukee. According to Burnham, "After sundown the northwestern sky was yellow

CRATERS ON THE MOON show in this sketch made by Bob Moody in Sallisaw, Oklahoma. Moody made his sketch five minutes before Sager photographed the Moon. Moody spotted the Moon without optical aid and sketched it with a 6-inch f/8 reflector at 45x and 90x.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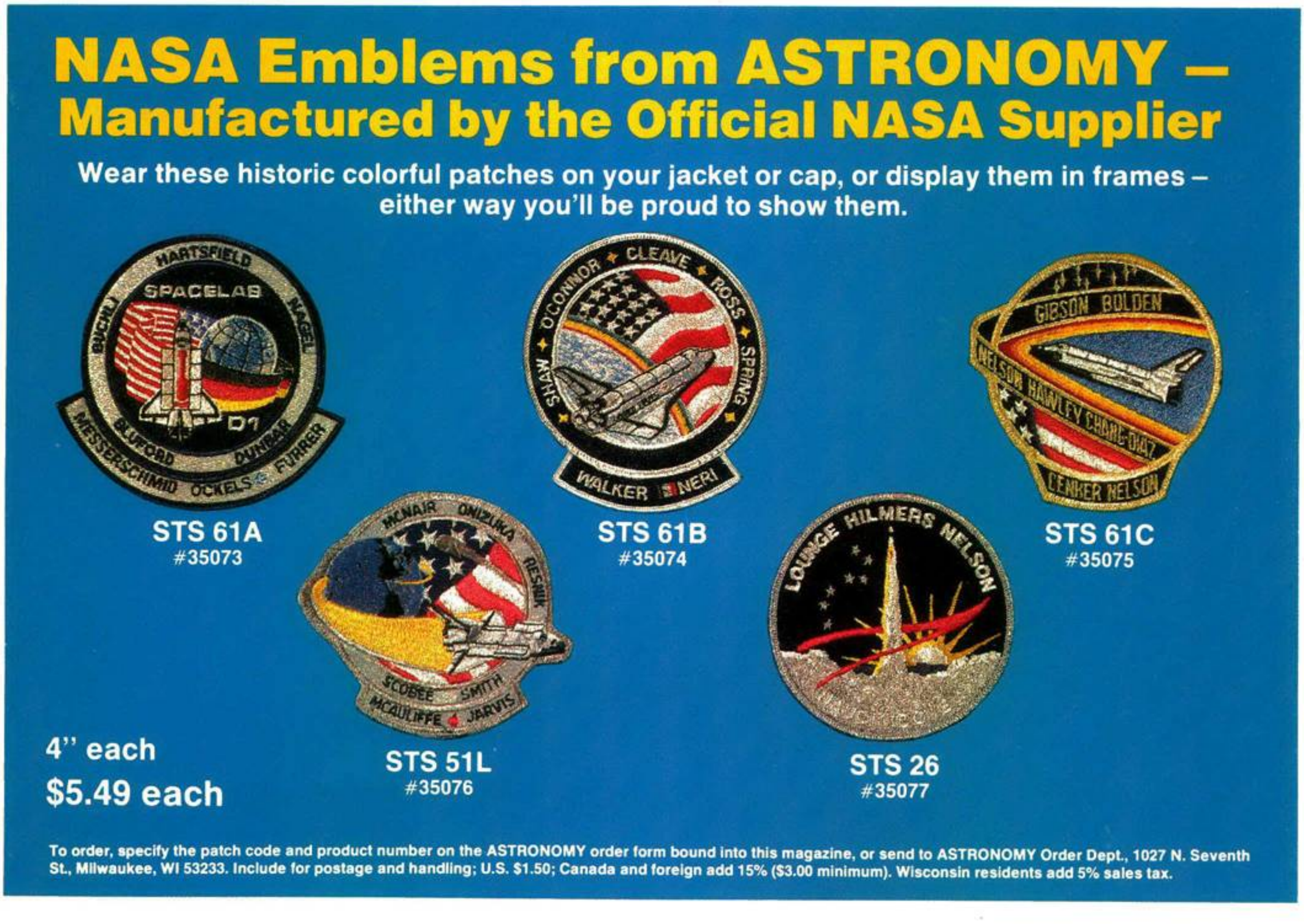
MTN Peaks
CRATER Humboldt



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(from dust and normal scattering) with dark cirrus streaks across it. Had it not been for the cirrus, I think I would have seen the Moon naked-eye."

Burnham used 8x30 binoculars to spot the Moon's thin crescent at 9:05 p.m. CDT. "The crescent was irregular in its edges. I thought I could see a hint of Earthshine on the unilluminated part, but I couldn't swear to this because the Moon was setting through the cirrus streaks and they intruded too much. The crescent extended less than half a circle — probably between a third of a circle and a half. Its altitude over a horizon of trees and a barn about a mile and a half away was about 2° or 3°."

JOURNEY TO SEE THE SOUTHERN SKY

After waiting nearly thirty years to see the wonders of the southern sky, Ivan Dryer of Van Nuys, California, finally got his wish. Last April Dryer traveled to Bora Bora in French Polynesia.

"The first strange thing is the Sun — it's in the wrong place! I arrived before dawn, and when the Sun rose in the northeast and arced across the *northern* sky, it seemed like afternoon rather than morning. When I left Los Angeles, Venus was above and a little south of the Sun. Now it was north of the Sun. And that night when the sky darkened, Orion was upside-down! Later on, the Big Dipper was just visible, bowl down, along the northern hills. And Sirius was high — way up high.

"After the sky fully darkened, the crown jewels of the southern Milky Way appeared. The Eta Carinae Nebula overwhelmed previous views I have had of M42 in Orion. I also saw globular clusters M22 and 47 Tucanae high in the sky, both surpassing the splendor of M13 in Hercules. Omega Centauri seemed to be in a league of its own, appearing like a white Chinese lantern in the sky.

"Everyone who has taken portable photographic equipment to the southern sky knows it isn't easy to adjust to the sky. (Polaris is really a blessing for the north.) Where is Octans, let alone Sigma Octantis? After scratching my head for a while, I used a compass, an inclinometer, and a lot of imaginary lines in the sky to make exposures slightly longer than those I could have made with a fixed tripod. Hypersensitized SRV 3200 had to do the rest.

"At about 3 a.m. I fell asleep. An hour and a half later I awoke. The camera and tripod were packed away and the film exposed, but I wanted another look at the sky. I went outside and was stunned to see, directly overhead, the Milky Way stretching from horizon to horizon. It really looked like an enormous edge-on spiral galaxy with a bulging nucleus, bifurcated by dust lanes and tapering symmetrically as each side fell toward the horizon. It was a spectacular view."

PERSEIDS PRODUCE FIREBALLS

This year the Perseid meteor shower produced a spectacular show because the Moon was absent from the sky, which allowed observers to see faint meteors as well as bright ones. Throughout the early mornings of August 11, 12, and 13, ama-

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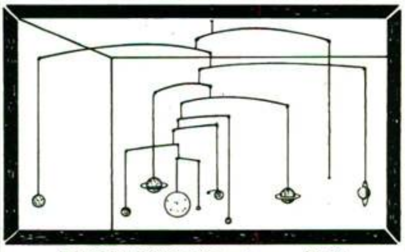

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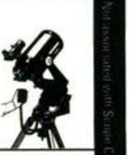

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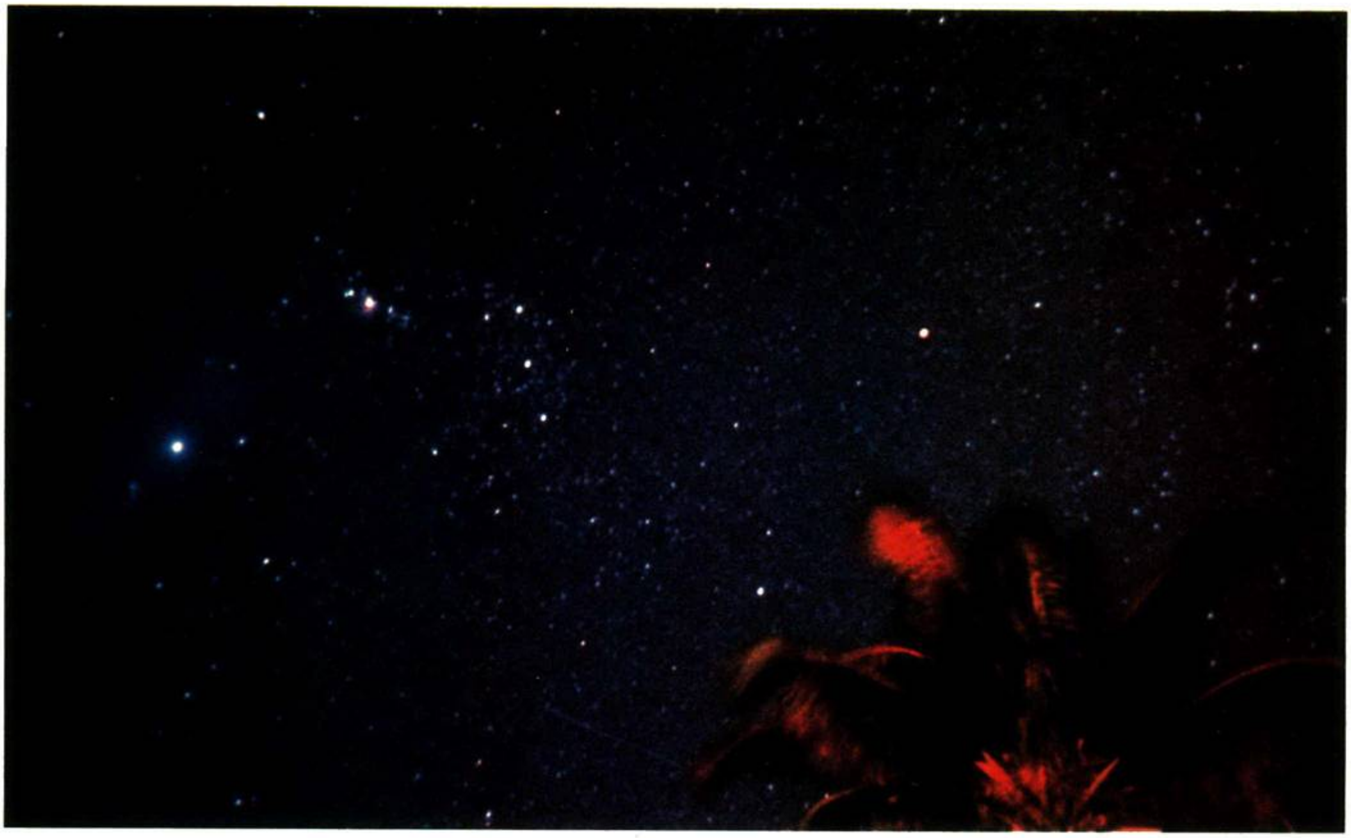

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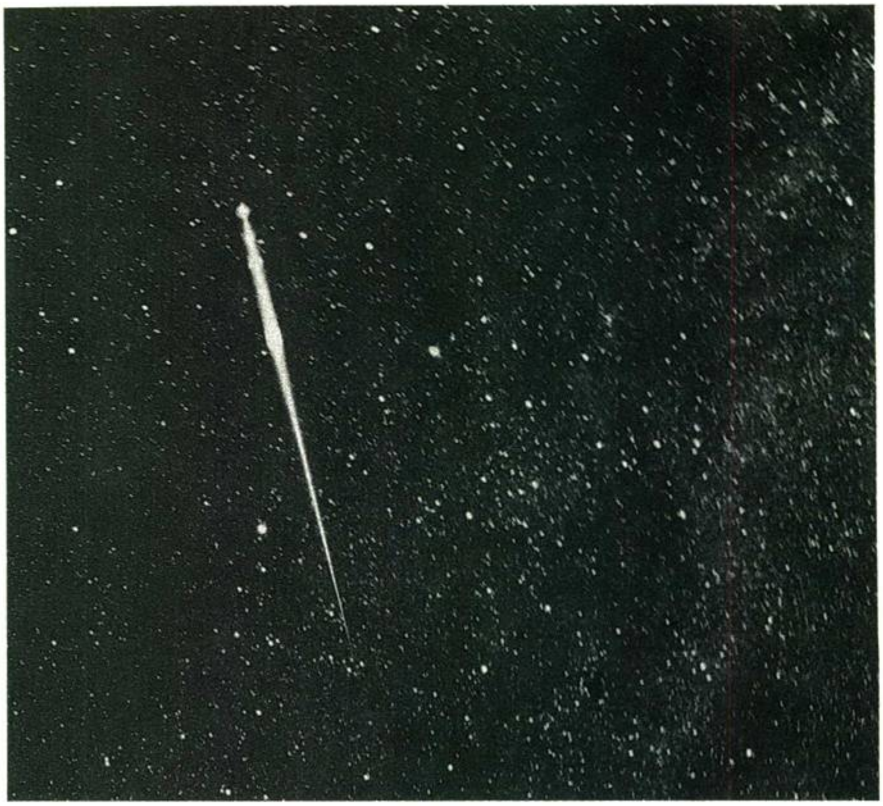
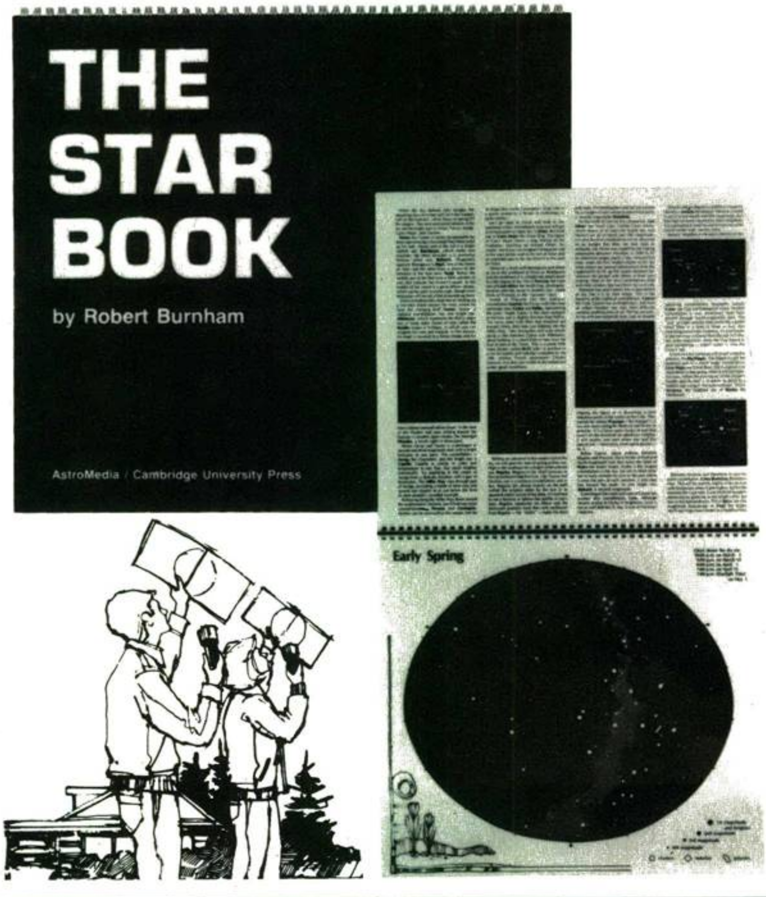
teurs witnessed dozens of bright Perseids sometimes crossing significant fractions of the sky.

At Stellafane in Springfield, Vermont, many of the two thousand attendees saw Perseid meteors throughout the morning of August 13. Every few minutes the silence on Breezy Hill was punctuated by shouts of "ooh" and "aah" as a bright meteor streaked across the sky. A group of amateurs including Arizona observer David Levy and Peter Jedicke of London, Ontario, pronounced a −6-magnitude fireball that traversed the sky from Perseus to near Sagittarius among the best they had ever seen.

In Halifax, Nova Scotia, Michael Boschat had an exceptionally good sky for the Perseid shower. "On the 11th," says Boschat, "I estimated a total zenithal hourly rate of 20. On the 12th I began observing at 9:00 p.m. and soon saw a magnitude −3 fireball moving from the radiant area all the way across the sky. The highest zenithal hourly rate came at around 11 p.m., when I counted 38. It was perfect for laying down and gazing up at the sky." — *David J. Eicher* □



A PERSEID ZIPS BY CASSIOPEIA in this photograph made during this year's Perseid shower maximum on August 12. Daryl Tucker used a 28mm f/2.8 lens, P3200 film, and a 75-second exposure. He developed the film at ISO 6400.



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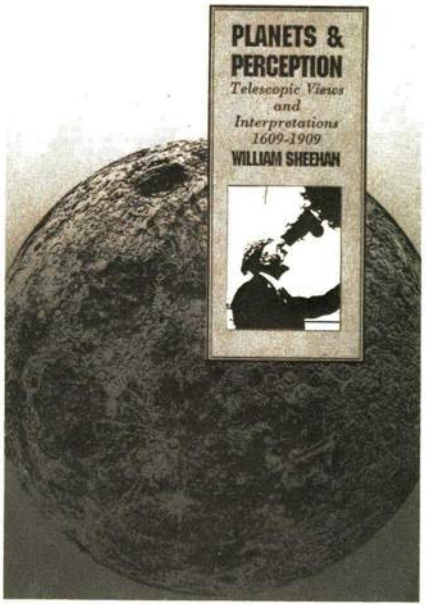

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*Astronomy Magazine, 10/84

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WINNING THE MESSIER MARATHON

"We did it!" my teenage daughter Lisa exclaimed.

We all took our turns at the eyepiece of the C8; everyone declared that he or she saw the faint glow of M30 against the brightening background of the eastern horizon.

It was 5:40 a.m. before I could regain the eyepiece for a last glimpse. But by then a blank, blue-gray field stared back at me. Only the setting circles indicated that somewhere in that soft glow an 8th-magnitude globular cluster in Capricornus competed with our nearest star — and lost.

The Charlotte Amateur Astronomers' Messier Marathon on March 19-20, 1988, ended as dramatically as it had begun almost ten hours earlier. We had set up our telescopes a few yards east of club members George and Mary's home in southern Union County, North Carolina. From the open, gently rolling farmland the three requirements for a successful marathon were met: light-pollution-free skies; clear horizons to the west, south, and east; and a cloudless, haze-free sky, provided twelve hours earlier by an accommodating cold front.

The Messier Marathon is an attempt to find and view each of the more than one hundred clusters, nebulae, and galaxies on the Messier list in a single dusk-to-dawn session. A marathon can be accomplished only when the Sun lies near the vernal equinox during the third week in March, because at that time none of the Messier objects lies too close to the Sun to be viewed. The Moon must also be near New, so reflected sunlight does not interfere. These conditions occur about every third year. And this was one of the favorable years.

George had organized the Messier list by right ascension and then subgrouped the M-objects by constellation. We all had copies of his computer print-out. Lisa, my daughter and observing companion, called out coordinates to me, which I transferred to the C8's setting circles. I glanced at the newly found object, called Lisa so she could view, checked my watch for the time, which Lisa recorded on the list, and peeked through the Telrad to see just where the telescope was pointed. Then the others took their turns at my telescope while Lisa and I looked through theirs.

At 8:02 p.m. Ron cried out, "I have M74!" His hand-built, computer-controlled, 10-inch telescope squatted within inches of the ground, its computer beeping occasionally and the stepper motors singing softly. We all had a glimpse. The race had begun.

Confidently we found M31, M32, and

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M110 (NGC 205) in quick succession. We bagged the two open clusters in Cassiopeia, M103 and M52, at 8:16 and 8:22, respectively. When we aimed at the coordinates for M33 in Triangulum, however, we found we had a problem.

"Damn! It's low and behind the house!" yelled George. We should have "done" it right after M74. But we blew it. By the time we realized our planning error, the broad, soft spiral was headed for the trees in the west. Not wanting to uproot our equatorially aligned scopes, we were dismayed until Bob said, "We'll get it in the copyscope!"

All thirteen of us swarmed to the north side of the house with the copyscope. The move brought us even closer to the trees in the northwest that ate up a bit of precious horizon. We star hopped northwestward from Beta Andromedae to Mu to Nu and easily found M31 to establish our bearings. Back to Beta. Now we swung an almost equal distance in the other direction from Beta and panned a bit south.

"There it is!" I said with relief, making room at the eyepiece for the others. "Let's look at the list to make sure we haven't overlooked a similar problem," Rob suggested. A brief glance at the list told us that M77, because of its southerly location near the celestial equator, was slipping away from us. Back we ran to the aligned scopes. Sure enough, we just barely managed to spot the 9th-magnitude spiral from the eastern horizon before the murk above the tree line swallowed it.

Now, quickly, M76, M34, naked-eye M45 — easier in the by-now dark sky. We were off and running, working well above the eastern horizon with an entire evening and morning and an array of stars, galaxies, nebulae, and clusters before us. M1, M79, M36, M37, M38 . . . Someone muttered, "We're going to have a problem with M30 in the morning." The message barely registered.

And so it went. M42, M43, M78 in Orion. The treasures of Gemini, Canis Major, Monoceros, Puppis, Hydra — until about 1:30 a.m. We had strolled through the labyrinthine Coma-Virgo cluster of galaxies, unaware that midnight had passed, confident of our mutually confirmed sightings. Many of our southerly targets now lay near the eastern horizon, promising to be more readily viewable after an hour or two. It was time for a break.

The proximity of the house, which had been a problem earlier, was now a blessing. Heat, facilities, and thoughtfully provided tacos, chips, dips, pickles, cinnamon rolls, brownies, and beverages rekindled the internal fires that had almost gone out in the cold. We marveled at the return of feeling to our fingers and toes.

We knew we should follow Lisa's example and settle into our sleeping bags for a nap, but a lack of common sense prevailed as we reveled in our accomplishments and the camaraderie of the previous hours. Just before her retreat Lisa had implored me to use the "ice-cube-in-the-shirt" trick should she be reluctant to rise when we went back out at 3 a.m. I knew I wouldn't have to.

We viewed more than just the Messier objects on our target list. At 2 a.m. a few of us snuck back out for a glimpse of Omega Centauri near culmination. Scores of other NGC objects and stars found their way into our eyepieces between M-object sightings in the more-or-less relaxed atmosphere that prevailed until 4:45.

Dick first detected the faint glow in the east that signaled coming daylight. Less than ten of us remained. Lisa counted the objects remaining and told me we had twenty-seven objects to go.

M56 almost did me in. I took five minutes to find its glorious light. Why? Search me! It was high in dark sky.

M29 at 5:14, M39 at 5:15, M72 at 5:16, M73 at 5:17. Three precious minutes for M2, recorded at 5:20. M15 in Pegasus at 5:21. At last I aimed at the coordinates of M30, the only object left on the list. I peered into the eyepiece. Darkness? Nothing? I looked through the Telrad. We're into the trees! My God, it hasn't risen for us yet!

I watched the tree line recede at an almost imperceptible rate in the eyepiece as the driven telescope held steadily on the sky beyond. I recalibrated and reset. M30 should appear nearly a half-degree higher above the horizon and a bit north. I looked. I scanned. I recalibrated and reset again. I implored silently. The five others who remained stood by in silence, their scopes ignored. The C8 was the only equatorially aligned instrument that remained. It was our only hope.

Agonizingly first one, then two small stars fought with the dawn and the atmosphere near the horizon. I could almost focus both of them to points. Then a smudge began to emerge. A product of my imagination? Focus. It won't focus!

Forty-five seconds lumbered by before I cried out, "There it is!" I quickly backed away from the eyepiece to allow Lisa her view of what, under ordinary circumstances, would surely have nonplussed the bulk of humanity.

It was 05:31. We had "won" the marathon. — *Tom Lorenzin* ☐

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Astronomy Books

A LONG LOOK AT A FLEETING PLANET

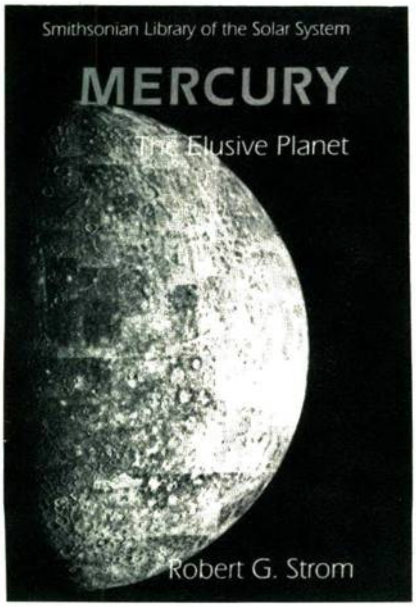
Mercury: The Elusive Planet by Robert G. Strom, (Smithsonian Institution Press, 1987), ISBN 0-87474-892-5, hardcover, 197 pages, $19.95.

Most astronomy buffs know that the main bodies in the solar system fall into two categories: gas giant planets like Jupiter and Saturn and the terrestrial ones like Earth and Mars. But every telescope owner has a more personally meaningful scheme: the planets you can examine with your telescope (such as the Moon or Jupiter) and those you need spacecraft eyes to see (Mercury, Venus, Uranus, etc.).

Well, all right. I'll admit you can see Mercury. That is, you can spot it several times a year with the naked eye if you know where to look, and a telescope will show you a small, lopsided, creamy white disk shimmering in a twilight sky. But you're not *really* seeing Mercury — at least no more than a rough outline. Mercury is just one of those indoor planets you explore while coping with the rigors of your favorite reading chair.

Nonetheless, I enjoyed Robert Strom's new book on Mercury precisely because it was an interesting, well-written account of a planet that doesn't look like much in the telescope. Although I can't see it any better in my scope for having read this book, I will look at that little white blob with a lot more interest than before.

Strom's book begins in paleolithic times, when early people must have begun wondering about the moving stars that appeared and disappeared shortly before dawn and after sunset. A few diagrams and a clear explanation show how any "inferior" planet (those that orbit closer to the Sun than Earth) can appear only this way. The chapter finishes by wrapping up the state of Mercurian knowledge as of the early 1970s.



Chapter two is the longest of the book's nine and details the *Mariner 10* mission. Launched in November 1973, *Mariner 10* was an unmanned spacecraft similar to those used to survey Mars (*Mariners 6, 7,* and *9*). It carried cameras, magnetometers, particle counters, and other instruments to examine Mercury and sample its environment. But the *Mariner 10* mission was pioneering for its time because it used a gravity assist from Venus to speed the craft toward its final target — a technique that has since become routine with the *Voyager* missions to the outer planets. In addition, *Mariner 10* encountered Mercury not just once but three times.

Even though we know the outcome, Strom's narrative of the mission still builds some suspense. Back then I followed the flight closely but had forgotten some of the narrow squeaks as instruments inexplicably switched to back-up mode or failed outright. By developing a clever "solar sailing" technique, mission control at JPL eked out the craft's meager reserves of thruster fuel long enough to permit — barely — all three encounters. It makes a good story and sets the scene for the rest of the book.

Chapter three covers the fundamentals of the Mercurian orbit and its completely weird day/year relationship. I won't describe here how it works — you'd need Strom's precise explanation and his clear diagram in front of you. One Earth sidereal day (one transit of a star to the next transit of the same star) differs from a synodic day (solar noon to solar noon) by about four minutes; on Mercury this difference is 118 Earth days. To put it another way, during one solar day on Mercury the planet rotates three times relative to the stars and makes two trips around the Sun!

The physical Mercury comes next. It is a ball of rock, one eighteenth the volume of Earth but with an iron core that's more than half the size of Earth's. Proportionally the core occupies a huge part of the planet. This one fact has had effects that range from creating a weak magnetic field to shaping the surface of the planet. (Though only one hundredth as strong as Earth's field, the polarity is identical — a compass on Mercury points north.)

Chapter five looks at Mercury's surface features and describes how the planet has been mapped — though unfortunately *Mariner 10* could photograph only about half the planet's surface. The U.S. Geological Survey maps reproduced in this book are only tokens, however; you'll find the real stuff in the *Atlas of Mercury* (NASA Special Publication 423).

But mapping is not all of the chapter's story. Strom points out that even the whole-hemisphere photos taken on the approach and departure tell of two kinds of terrain. At first glance the place looks like the Moon — craters everywhere. But there are no large expanses of dark basalt like the lunar maria. Instead, Mercury has "smooth plains" and "inter-crater plains." The smooth plains are Mercury's closest analogue to the maria, but they are about twice as reflective and much less cratered. And the Moon entirely lacks inter-crater plains because its oldest surfaces have been cratered to saturation.

Appropriately, chapter six focuses on impact craters, the solar system's most pervasive landform. (The fact that you don't have one in your backyard is merely a statistical deviation.) Here, Mercury most resembles the Moon and Mars. In fact, at a quick look the Caloris basin impact on Mercury is identical to the Moon's Mare Orientale basin — though Strom, confusingly, picks Mare Imbrium as the lunar analogue for Caloris. Many familiar lunar impact features are repeated on Mercury: ejecta blankets, central peaks, radial valleys, secondary impact craters, and so on. But a careful count of crater sizes shows that Mercury somehow escaped the light sprinkle of rocks that hit the Moon and Mars in the last 4 billion years. Why this is, no one knows.

The next chapter deals in detail with the two kinds of plains, which together occupy about 60 percent of Mercury's surface. To us, the Moon is a brilliant white object, especially at Full. But this impression is misleading, because the Moon is really only as reflective as fresh asphalt pavement. Mercury, on the other hand, is twice as reflective as the Moon. We know the lunar surface is rich in titanium and iron, elements that darken rocks. Because Mercury's surface is so bright, then it must be greatly depleted in titanium and iron. Where did they go? They probably drained into the interior when the planet melted throughout and its giant iron core formed.

The energy to drive this planetwide melting came from the heat of accretion and the radioactive decay of elements in the rocks. Heat was also added when the

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planet's original spin rate was slowed. In any case, as it was heated throughout, Mercury swelled by about 1 percent. This was enough to create tension cracks (faults) in its crust. Then, as the planet cooled, it shrank, and pieces of the now-rigid crust were rammed together hard. Many of the tension cracks became thrust faults as the edge of one piece rode up and over the edge of the adjoining one. The visible result, discussed fully in chapter eight, is a network of rocky welts that run long distances over the surface, cutting across craters and smooth plains alike.

Strom's last chapter rolls the details into a coherent history of Mercury. Although it is a world with several unique characteristics, Mercury makes little sense without comparisons to the Moon and Mars. On those now long-dead worlds, geology "turned on" and ran its course for more than a billion years before the fires cooled. Yet even the Moon has been active in comparison to Mercury, which seems to have shut down its geological engine within the first 700 million to 800 million years after forming.

Mercury finishes with a good list of additional readings, an excellent fourteen-page glossary, a summary of orbital and physical data on the planet, a list of named surface features that gives location and size, and a brief but useful index.

No doubt other specialized works on Mercury will emerge in the years to come, but for the general astronomy buff this is the Mercury book to get. Couple it with the NASA *Atlas of Mercury*, and you've got this corner of the solar system wrapped up nicely. — *Robert Burnham*

NOT EXACTLY FOR RANK BEGINNERS

The Monthly Sky Guide by Ian Ridpath and Wil Tirion, (Cambridge University Press, 1987), ISBN 0-521-33921-9, paperback, 63 pages, $7.95.

According to the back cover, this book is supposed to be "the ideal guide to help beginners find their way around the sky." I, therefore, began to read *The Monthly Sky Guide* as if it were the first astronomy book I had ever read. It wasn't long before I realized the package was deceiving: this wasn't a beginner's book but a cursory survey of the night sky that had a thrown-together feel.

Thumbing through the book, I was impressed with Wil Tirion's sky maps (the maps are the same type as in his *Sky Atlas 2000.0*). But as I took a closer beginner's-eye view of the maps and text, I began to have some doubts. I wondered what the numbers followed by a lower case "h" meant. What did "DST" mean in the time chart at the bottom of each monthly map? Just how faint is a 5th-magnitude star? If I were a rank beginner, I would never have understood the maps, because the explanations for how to use them are skimpy at best. Nowhere in the text did I find anything about how to use the coordinate system of right ascension and declination, yet the maps are criss-crossed with these terms.

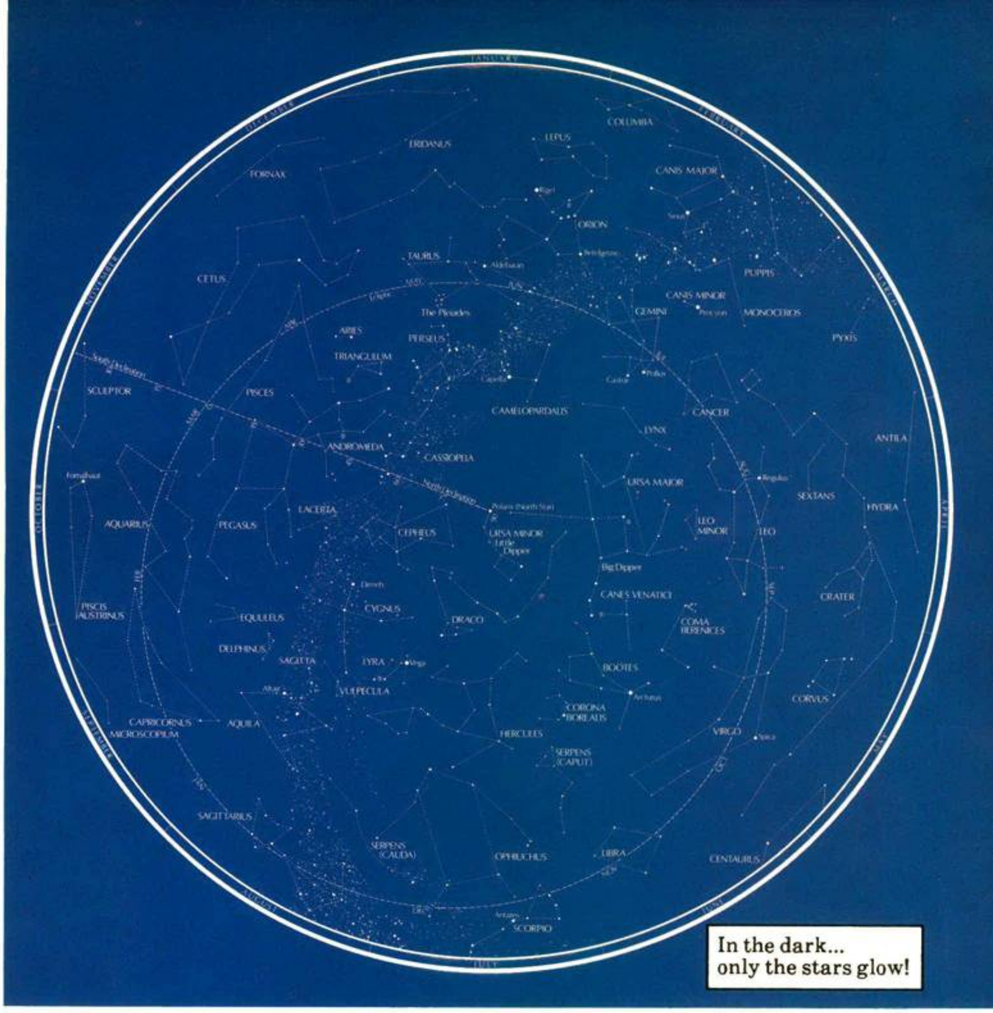
Even more confusing, the author states that the monthly star charts "are designed to be used for stargazing with the naked eye." In the next paragraph, however, he discusses using binoculars and mentions that many of the objects to be covered in the monthly text will be visible only with some kind of optical aid. Is this book for naked-eye or for telescopic viewing of the night sky? Looking at the type of objects presented in the constellation maps and discussed in the text, I think someone without a telescope or binoculars will feel left out.

Another problem with this book is that the Greek letters, used to identify certain stars on the maps, aren't keyed to a chart of the Greek alphabet. It would have been convenient for the reader who doesn't know what, say, Eta or Zeta look like to have had such a chart with all the Greek letters and their corresponding names placed somewhere in the book for reference.

An index would also have been a big help to the reader. To find references to M31 or the Double Cluster, you have to know the constellations where these objects can be found. The same is true for meteor showers that occur only in certain constellations in certain months. In fact, to find information on a particular constellation, you must thumb through the book until you stumble across the constellation name. The table of contents is of little help: it consists of the introduction and the months of the year.

Eventually the novice stargazer will figure out that DST stands for daylight saving time. The DST acronym should have been defined in the (all too brief) four paragraphs used to explain how to use the maps. But that is not the end of the puzzle, for the best DST to use with each map of the *Sky Guide* is also given for the months when daylight savings time is not used in the United States. The beginner must deal not only with cryptic information but also with how that information is correctly used.

Not to be totally sour grapes about this book, there is some useful information that seems well presented. Preceding the text for each month is an all-sky map of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the northern sky. These maps show the sky visible from 30° north. The horizons for 40°, 50°, and 60° north are marked. A companion scale for the magnitudes of the stars (down to magnitude 6) is given across the bottom of the page. In each month's map text the location and magnitude of the planets visible that month are given for 1988 through 1992. For those eight months when a meteor shower occurs, the author tells us what causes the shower, how each shower got its name, and how best to view it. The monthly map text also features constellation descriptions, which include a little mythology as well as interesting objects located in each star group. However, as much as I like to read about mythology, too much space was devoted to the subject. Much of the text space used for mythology could have been used to explain more basic night sky concepts.

Interspersed with the monthly text are maps showing smaller sections of the sky of special interest for that month. The maps show galaxies, nebulae, variable stars, clusters, and many named and numbered stars. Because these maps are of different scales, the illustrator thoughtfully included the outline of a fist held skyward to indicate the map's scale.

I was disappointed by this abbreviated introductory work, especially because Cambridge University Press has a reputation for producing better-quality books. I feel the author could have created a more practical book if he had adequately explained how to use the maps and optical aids and presented more information in general. A beginner will certainly flounder if this is the only book he uses as his first guide to amateur astronomy. Unfortunately the celestial cartographic skills of Wil Tirion do not outweigh the book's textual flaws. This imbalance makes for a weak book. — *Robert A. Garfinkle*

A LOOK AT THE EXTREMES OF GENIUS

Who Got Einstein's Office?: Eccentricity and Genius at the Institute for Advanced Study by Edward Regis, (Addison-Wesley, 1987), ISBN 0-201-12065-8, hardcover, 316 pages, $17.95.

If you are looking for a book about the stars of the night sky, this is not it. The "stars" in *Who Got Einstein's Office?* are the men and women of the Institute for Advanced Study located in Princeton, New Jersey. Founded in 1930, the institute was designed to attract the best and brightest scholars and theorists. The faculty members were (and are) the "so-called prima donnas of science." Their task is to "discover the secrets of the universe." These scholars are allowed to work on any subject they want without any requirement to teach, publish, or prove anything.

Though Albert Einstein, John von Neumann, and J. Robert Oppenheimer are probably the best known of those to work at the institute, the author gives great snapshotlike histories for many others: American physicist Murray Gell-Mann, who explored the bizarre world of subatomic particles and coined the word "quarks"; Austrian mathematician Kurt Godel, who showed that certainity does not exist in any mathematical system; Chinese physicists Tsung-Dao Lee and Chen Ning (Frank) Yang, who studied K-mesons and their strange behavior; and Freeman Dyson, who is known for his work on electrodynamic theory and extraterrestrial civilizations. Ed Regis gives insight into who these men were and how they worked.

I was saddened, though, to read that for the most part they worked independently and rarely cooperated on the same project. Often big egos got in the way and many of the younger scientists felt they would be bothering the older ones if they asked for help.

This book offers glimpses into the extreme conditions of genius. You sense the loneliness that drove a brilliant mathematician like Godel to starve himself to death because he thought people were out to poison him. At the other extreme we meet John von Neumann, who knew how to throw good parties, developed the stored-program computer, and always dressed like a banker even when riding a mule to the bottom of the Grand Canyon. The anecdotes about the institute people breathe life into this book and make it a pleasure to read.

The reader does not have to be a scientist to understand the material presented because Ed Regis has a lively writing style that gives you a sense of the place and the scientists. He brings down to the layman's level all of the highly technical scientific discoveries he covers.

Intertwined with the biographical information are brief explanations of some of the discoveries made in physics, mathematics, and astrophysics. Two of the many theories discussed are Dyson and Leonard's work on the stability of matter and Benoit Mandelbrot's work with fractals and the irregularity of nature. Regis even found room in the book to write about Franz Moehn, the institute's chef. Lunchtime gatherings and lectures play a large role in the intellectual life of the institute.

I thoroughly enjoyed reading this book. When I finished it, I had a clear sense of what it is like to be appointed to work in such a lofty tower as the institute. I can heartily recommend this book to anyone interested in the people behind so many theories that drive the modern scientific world. — *Robert A. Garfinkle*

IN SEARCH OF METEOR SHOWERS

Meteor Showers: A Descriptive Catalog by Gary W. Kronk, (Enslow Publishers, Inc., 1988), ISBN 0-89490-072-2, paperback, 296 pages, $24.50.

Virtually every observer of the night sky has seen meteors flashing grandly across the sky or zipping across a telescope's field of view. Alert observers have learned to quickly aim binoculars at a glowing meteor train and watch in fascination as the winds aloft twist the ghostly train into serpentine shapes. Often such meteors are random incidents and the observers who witness these events just happen to be in the right place at the right time.

But it's possible to increase your odds of seeing such spectacles by observing when there are more meteors are in Earth's interplanetary neighborhood than usual. Such periods are called meteor showers.

Meteor showers occur when our planet's orbit intersects the orbit of a meteor stream, a fragile, changing path composed of remnant comet particles. If this chance meeting occurs during the nighttime hours, you may witness meteors, occasional fireballs, or, in rare instances, an exploding meteor or bolide.

To quantify the best-known and most reliable meteor showers (as well as several little-known showers, including some detectable only through radar and radio-echo techniques), author Gary Kronk has written a book that will find favor with nearly every observer of the night sky.

The volume contains data on the 112 most active meteor radiants in the sky. For each shower the author includes the dates of discovery and of peak activity, the average duration, average meteor brightness and color, longevity of an average train, and other pertinent information.

In some respects Kronk's book resembles a well-composed, fleshed-out outline. This is not a criticism; rather, it is a comment upon the apparent effort put into making the book exact and correct in every detail. And the reader will benefit from Kronk's attention to detail.

The volume is organized around twelve chapters, one for each month. Within a monthly chapter each meteor shower is listed alphabetically according to its apparent constellation of origin. The author describes the showers in a forthright manner, and he uses a three-part format: observer's synopsis, history, and orbit.

In the observer's synopsis Kronk includes coordinates of the shower's radiant, average duration of the shower (including dates), the hourly rate when appropriate, and similar data of interest to an observer.

The history category provides details of the shower's discovery, predictive data leading to confirmation of the radiant, anecdotal accounts of observers, information about the parent comet, and, for post-1946 events, the role radar played in pinning down the statistics and values that are used to describe the shower. The history section for each shower is some of the best cloudy night reading meteor hunters will find in print.

In the orbit category for each shower, values that describe the elements of the meteor stream are given. These data were generated through photographs, visual reporting, and radar.

In addition to an index, Kronk's book includes four short appendices. They list definitions, shower associations (a listing of the probable parent bodies of major showers), the D criterion (a mathematical tool used to differentiate meteor streams from occasional or sporadic meteors), and the sources used by the author.

Material in the book is well documented. Kronk has pulled together an impressive amount of information about those tiny interlopers from space that constantly bombard the Earth.

Kronk intended this book to be used. He does not linger over presumed origins for meteor showers, and he doesn't attempt to trace each shower back to a parent comet (although this information is included in most cases). He also does not discuss the chemical properties of meteorites or the history of meteor showers.

But any reader who wants to know when and where to look for a meteor shower on nearly any night of the year and to learn what visual characteristics to expect will find Kronk's book a bonanza. Nontechnical, informative, and aimed at all readers curious about meteors, this book will serve more as an active reference than a volume to read and then relegate to your astronomy book shelf.

Before leaving for an observing session, dip into Kronk's book to add a dash of meteoritic flavor to the night. — *Gail O. Clark* ☐

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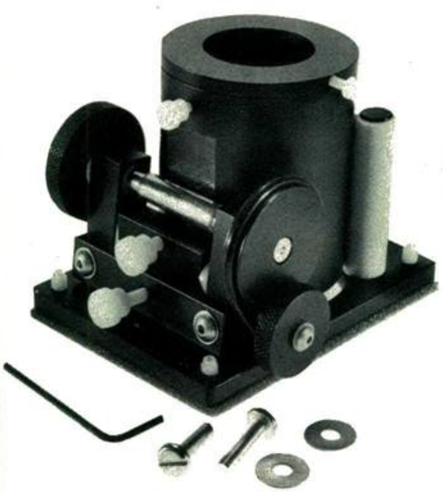
Focuser for 1¼-inch and 2-inch eyepieces, (AstroSystems, P.O. Box 1183, Longmont, CO 80501; (303) 678-5339), $99.95.

The AstroSystems eyepiece focuser is intended for visual observing and astrophotography. It accepts either 1¼-inch- or 2-inch-diameter eyepieces. The focuser barrel slides in and out on Teflon bearings, as do all the focuser's moving parts. Nylon thumbscrews can be tightened to control friction and unwanted movement.

Although designed for a flat-sided tube, the focuser comes with four nylon spacer screws that pass through the corners of the flat mounting plate. These allow the focuser to make contact with a curved tube at the edges of the flat plate. A thin, foam-rubber pad mates the plate to the tube, forming a relatively light-tight seal and smoothing over any minor irregularities in the tube's finish.



The focuser comes with installation and upkeep instructions.

OBSERVING ACCESSORIES

Field Finder, (Spectra Astro Associates, 8726-D South Sepulveda Boulevard, Suite 441, Los Angeles, CA 90045; (213) 649-3842), $7.95.

Designed to help you plan astrophotography of starfields, Field Finder is manufactured in four versions — one for each of several popular star atlases. A transparent sheet of heavy plastic about 8½ by 11 inches in size, each overlay sheet has printed upon it the rectangular outlines of a 35mm camera's field of view using several different focal length lenses (or telescopes). Each overlay also has circles on it for 4.5° and 7° fields of view (corresponding to the bull's eye circles on a Telrad aiming device).

Field Finder overlay sheets are available for *Sky Atlas 2000.0* (regular, desk, and field editions) and for *Uranometria 2000.0* at $7.95 each. All markings are printed in black, except in the field-edition version, which uses white.

Observer's Notebook by the Los Angeles Astronomical Society, (c/o Randy Kolar, 7 Vercelli, Irvine, CA 92720; (213) 333-5685), notebook and binder, $17.

The *Observer's Notebook* is a loose-leaf book encased in a plastic wrap-around protective case. It includes a print-out of the entire *New General Catalogue* (magnitudes, types, epoch 2000.0 positions), the Yale *Bright Star Catalogue* (positions, magnitudes, color indices), and fifty pages of blank observing forms. It was compiled by Luis Ashelford, Randy Kolar, and Kaaren Yeghiazarian.

SLIDES

The Sky at Many Wavelengths by Christine Jones, William Forman, and Carolyn Stern, (Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112; (415) 337-1100; 1988), ISBN 0-937707-14-7, 11 slides and 39-page booklet, $15.95.

This collection of slides provides a look at "the invisible sky" — the universe at nonoptical wavelengths. It begins with a diagram of the electromagnetic spectrum and a painting of the visible sky centered on the Milky Way, presumably for orientation. The set then shows you the same view of the sky in the radio (wavelengths: 73 centimeters and 21 centimeters), the microwave, the infrared, and the x-ray and gamma-ray regions of the spectrum. Individual slides also map molecular clouds and infrared and x-ray sources.

The accompanying booklet has detailed captions, each several paragraphs long, for every slide in the set and (at the end) a nontechnical reading list. All the slides are in color (false color) except for the visual sky, which is black and white. The authors are astronomers at the Harvard-Smithsonian Center for Astrophysics.

SOFTWARE

Apollo 18: Mission to the Moon for Commodore 64/128 computers and IBM compatibles, (Accolade, Inc.), Commodore version, $29.95; IBM version, $39.95.

Apollo 18: Mission to the Moon is, first of all, a simulation re-enactment of mission activities from several *Apollo* flights. It does not attempt to re-create the actual *Apollo 18* mission that NASA was planning and then cancelled when funding dried up. The software does a decent job within the memory limitations of the machine (I ran it on a Commodore 64 only), yet *Apollo* also has enough "arcade action" to hold the attention of gamers.

The Commodore version comes on a two-sided "flippy" diskette that is copy-protected but doesn't beat your disk drive to pieces as some copy-protection schemes do. It makes excellent use of digitally stored voice communications that are hard to distinguish from the real thing. The graphics and other sound effects are also well done.

The scenario opens with a view of mission control while a voice intones, "T minus 15 and holding." You switch to the telemetry screen and manually activate several systems via the keyboard. Once the countdown begins, you and the joystick get quite busy.

The instruction manual was overly terse in describing how to keep the spacecraft under control during launch. As a result, I crashed about five times before I figured out what I was supposed to do! You use the joystick's FIRE button to initiate events, such as stage separation, on the trip into orbit.

While you're doing this, you also have to keep the spacecraft's gyros in balance by jiggling the stick left or right. The manual neglects to say which direction corrects which imbalance and this cost me a couple more launches. The events come more and more frequently as the ship nears orbit. I rapidly concluded that anyone driving this thing had best forget about watching the rocket's flight on the screen. Instead, watch the flight when someone else is trying to fly it.

The remainder of the simulation involves mid-course corrections, satellite recovery, docking, lunar landings, Moon walks, and the return to Earth.

There's no provision for saving flights in progress, but you can pause the action to recheck the instructions or take a break. If you mess up during launch, you must return to the telemetry screen and start over. With failures later in flight, you're allowed to continue with a limited mission — for instance, you don't get a Moon walk until you first land successfully on the Moon.

Aside from the lack of instructions I mentioned, I was pleased with *Apollo 18* and think anyone who tries this package will be too. — *James Bailey* ☐

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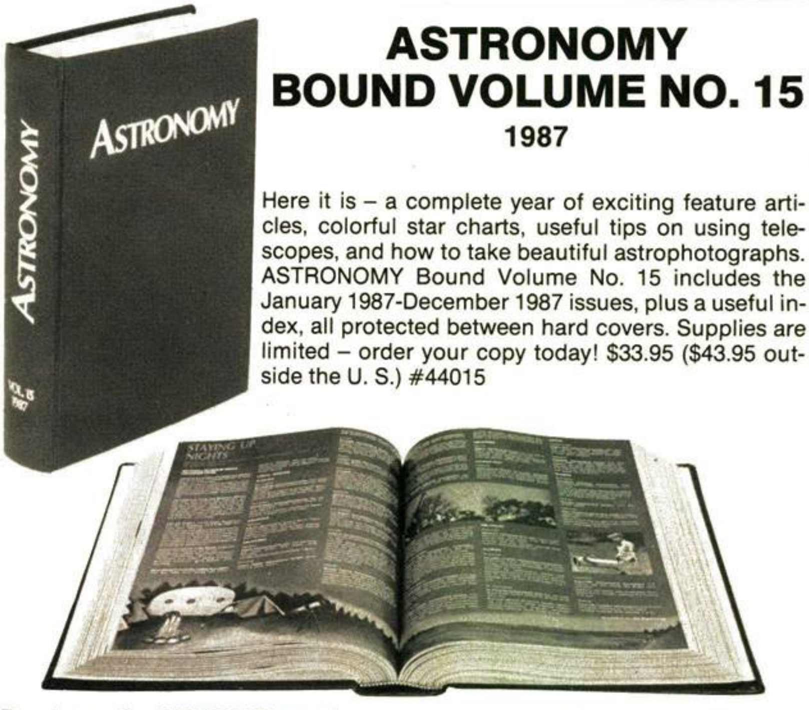

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FOR SALE – 8" f/8 Newtonian, massive mount, two finders, solar filter, and extra secondary. 6" blank, ground tool, and compounds. Package deal. Best offer. Contact K. Wlasuk, 111 Sunnyside Road, Syracuse, NY 13224. Phone (315) 446-1313.

FOR SALE – Celestron Super Polaris mount with tripod and single-axis motor drive. $350. Bausch & Lomb 9mm 1-1/4" illuminated reticle eyepiece. $55. Telrad finder. $20. Contact Terry Smith, P.O. Box 93, Linton, IN 47441. Phone (812) 847-2532.

FOR SALE – 10" Newtonian with excellent Coulter optics, Novak supports, Meade research-grade mount, three eyepieces, Barlow, filters, rotating rings, drive corrector, and photo accessories. $995. Contact Bob Schmall, 109 Skyline Drive, Appleton, WI 54915. Phone (414) 757-6710.

FOR SALE – Eleven back issues of *Sky & Telescope* from April 1986-February 1987 (Halley's Comet). $20 postage paid. Contact Henry Hsu, 35-46 74th #507, Jackson Heights, NY 11372. Phone (718) 639-3740.

FOR SALE – Celestron C-90 with wedge, fork mount, motor drive, diagonal, Kellner 18mm eyepiece, 2.5x Barlow, photo adaptor, and foam case. Everything in good to excellent condition. Retails for $1,000, will sell for $620. Phone Sergio Reyes at (301) 422-9232.

FOR SALE – University Optics 1.25" 18mm Ortho. $22. Pentax screw-type T-ring. $8. 0.965 2x Barlow. $8. 0.965 Porro prism $18. 0.965 Sun filter. $8. ASTRONOMY from November 1977-December 1987, four issues missing. $110. *Sky & Telescope* from August 1985-1987. $28. Contact Bob Woodruff, 1759 Piikea Street, Honolulu, HI 96818.

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FOR SALE – Odyssey I 13.1" f/4.5 Dobsonian with 2" focuser, 2" finder, and Telrad. Ready to use, one year old, excellent condition. $650 firm. You pick up. Contact Doug Kasel, 4424 North Wyss Lane, Peoria, IL 61614. Phone (309) 685-2304 mornings only.

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Meetings and Events

October 13-15
MAPS '88 Conference, Durham, New Hampshire, and Boston, Massachusetts. Sponsored by the Middle Atlantic Planetarium Society. Contact: Ellie Milliken, 8 Evans Drive, Dover, NH 03820. Phone: (603) 742-3953.

October 14-16
Stella Della Valley II Star Party, Camp Onas, Ottsville, Pennsylvania. Sponsored by the Bucks-Mont Astronomical Association. Contact: Ed Radomski, 36 Far View Road, Chalfont, PA 18914. Phone: (215) 822-8312.

October 19-22
24th Annual Conference of the Great Lakes Planetarium Association, Bowling Green, Ohio. Contact: Dale W. Smith, Department of Physics and Astronomy, Bowling Green State University, Bowling Green, OH 43403. Phone: (419) 372-8666.

October 29
Telescope Users Clinic, Rio Hondo College, Whittier, California. Sponsored by the Western Observatorium, Inc. Contact: Pat Heath, 6235 Painter #A, Whittier, CA 90601. Phone: (213) 696-0619.

November 3-6
6th Annual Deep South Regional Stargaze/Southeast Region Astronomical League Convention, Percy Quin State Park, McComb, Mississippi. Sponsored by the Pontchartrain Astronomy Society. Contact: Barry Simon, 820 Emerald Street, New Orleans, LA 70124. Phone: (504) 283-7592.

November 10-12
Pacific Planetarium Association Fall Conference, Santa Rosa, California. Contact: Ron Oriti, Santa Rosa Junior College Planetarium, 1501 Mendocino Avenue, Santa Rosa, CA 95401.

November 16
Centennial Celebration and Rittenhouse Medal Award Ceremony, Franklin Institute, Philadelphia, Pennsylvania. Sponsored by the Rittenhouse Astronomical Society. The award will be given to Eugene and Carolyn Shoemaker for oustanding achievement in astronomy. Contact: Rittenhouse Astronomical Society, Box 24716, Philadelphia, PA 19111.

February 2-5
5th Annual Winter Star Party, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

Submit announcements at least four months before the date of the meeting or event.

When you write organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. ☐

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ANNOUNCEMENT – Morehead Planetarium is accepting applications for a two-year internship beginning fall 1989. Applicants must be admissible to the University of North Carolina-Chapel Hill Graduate School. Annual stipend of $10,000. Contact Intern Selection Committee, Morehead Planetarium, CB#3480, UNC-CH, Chapel Hill, NC 27599-3480.

ANNOUNCEMENT – Satellite/Space Information News Net and Seismic Precursor Net stimulate southern California hams into scientific discussions/calculations. Send #10 SASE with $2 for summary. Written observations welcome. Contact SPN, Box 306, Lakewood, CA 90714.

FOR SALE – ProMaster Spectrum-7 28mm f/2.8-22 camera lens. Range of 10" to infinity. 72° field. Fits Minolta cameras. Has covers for both ends and lens cover strap. Contact Tom Rankin, 170-B North Elting Road, Highland, NY 12528. Phone (914) 255-7074 evenings.

FOR SALE – Vivitar 85-210 Zoom and Vivitar 28-85 Zoom. Both with Olympus mount. Very good condition. Both for $100, $55 each. Contact Dennis Slota, 625 West Humbolt #106-3, Battle Mountain, NV 89820. Phone (702) 635-5961.

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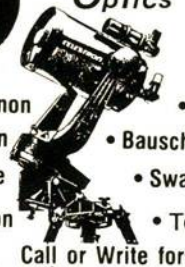

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Readings and Resources

Mercury (page 22)

Atlas of Mercury, (NASA SP-423, 1978). The best atlas for armchair exploring. It contains maps, photos, and names of features.

Geology of the Terrestrial Planets, edited by Michael Carr, (NASA SP-469, 1984). A semitechnical survey with many photos and diagrams.

Mercury: The Elusive Planet by Robert G. Strom, (Smithsonian Institution Press, 1987). A good, popular level science summary of the planet.

William Herschel (page 40)

"Description of a Forty-Feet Reflecting Telescope" by William Herschel, *Telescope Making #3*. Herschel's explanation of how he built and used the instrument.

William Herschel and the Construction of the Heavens by Michael A. Hoskin, (Norton, 1963). An analysis of Herschel's theories on the Sun's proper motion and the structure of the Milky Way.

William Herschel: The Pioneer of a New Era in Astronomy by Angus Armitage, (Doubleday, 1963). A brief history of Herschel's life and an examination of his contributions to astronomy.

Gravity Ring (page 60)

"Unusual Radio Source MG1131 +1456: A Possible Einstein Ring" by Hewitt, Turner, Scheider, Burke, Langston, and Lawrence, *Nature*, June 9, 1988. The paper explaining the discovery, with technical background details.

Gravity's Lens: Views of the New Cosmology by Nathan Cohen (John Wiley & Sons, Inc., 1988). A readable guide to new problems in deciphering the structure of the universe.

Great Astrophotos (page 82)

Astrophotography, second edition, by Barry Gordon, (Willmann-Bell, 1985). A basic beginner's how-to book.

Astrophotography for the Amateur by Michael Covington, (Cambridge University Press, 1985). A well-illustrated, detailed guide.

Winter Sky Wonders (page 94)

Atlas of Deep Sky Splendors, 4th ed., by Hans Vehrenberg, (Cambridge University Press, Sky Publishing, and Treugesell-Verlag, 1983). Lavish picture portfolio showing long-exposure photos of many winter deep-sky objects.

Astrophotography Gadgets (page 107)

Handbook for Star Trackers by Jim Ballard, (Sky Publishing, 1988). A new book about building and using camera platforms.

CREDITS

Cover: Jack Newton (20-inch f/5 telescope, Kodak VRG film with a cold camera, 30-second exposure, and a light-pollution filter); *page 4*: Jerry Schad (35mm f/2 lens, 3M 1000 film, 20-second exposure, and a CC 20M filter); *page 12*: European Southern Observatory; *page 14*: David Malin, Anglo-Australian Telescope; *page 18*: David J. Eicher; *pages 22-23*: painting by Ron Miller; *page 24*: NASA/JPL; *page 25*: painting by Ron Miller; *page 26*: NASA/JPL (P-14855); *page 27*: S. Zohar and R. M. Goldstein, courtesy of Pamela Clark, JPL; *pages 28 and 29*: NASA/JPL; *page 30*: NASA/JPL (P-14470); *page 31*: NASA/JPL (P-14918 B); *page 32*: Pamela Clark; *page 33*: U.S. Geological Survey, courtesy of Paul Spudis; *pages 34-35*: painting by Thomas L. Hunt; *pages 40-41*: painting by Bruce Bond; *page 42, top left*: William Herschel Society, *bottom right*: Adler Planetarium, Chicago; *page 43*: Ann Ronan Picture Library; *page 44*: Royal Astronomical Society; *page 46*: *Philosophical Transactions of the Royal Society of London*, 1785; *page 47*: Ann Ronan Picture Library; *pages 48-49*: William Herschel Society; *page 50*: Royal Astronomical Society; *page 51*: *Beschreibung des vierzigfussigen reflektirenden Teleskops* by William Herschel, (Leipzig, 1799); *pages 52-53*: *Philosophical Transactions of the Royal Society of London*, 1784; *page 61, top*: MIT Lincoln Laboratory, *bottom left*: Jacqueline N. Hewitt, Haystack Observatory, *bottom right*: Roger Lynds, National Optical Astronomy Observatories; *page 73*: map and diagrams based on information provided by David Dunham of the International Occultation Timing Association; *page 74*: sketch by Jose Olivarez (6-inch f/7 reflector at 170x), August 7, 1988, Great Red Spot table transit times courtesy of Jim Van Nuland of the San Jose Astronomical Association; *pages 83-87*: all photos by Jack Newton; *page 95*: Tony Hallas and Daphne Mount; *page 96, top*: Chris Schur, *bottom*: Jack Child; *page 97, top*: Dan Gordon, *bottom*: Robert Reeves; *page 98, top left and right*: Ronald Royer, *bottom*: Jack Newton; *page 99*: Martin C. Germano; *page 100*: Richard Berry; *page 101, top*: Jason Adamik, *bottom*: Jeffrey L. Jones; *page 102, top and middle left*: Steven J. Simmerman, *bottom*: Jerry Schad; *pages 102-103*: Martin Hale; *page 103, top right*: Jeffrey L. Jones, *bottom*: Scott McGurk; *page 104, top*: Kim Zussman, *bottom*: Jim Bailey; *page 105, left*: Richard Berry, right: Lee C. Coombs; page 107-110: M37 photos by Hal Jandorf, all other photos by Art Schmidt; *page 114, left and top right*: Donald C. Parker, *bottom right*: Isao Miyazaki; *page 115, left*: William W. Sager, *right*: Bob Moody; *page 117*: Ivan Dryer; *page 118*: Daryl Tucker; *page 120*: illustration by Bryan Peterson.

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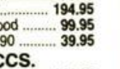

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Exotic Spinning Stars

The odd but regular radio signals of pulsars presented a scientific mystery that required imagination and new data to solve.

Roundup of 1988 Mars Observations

Amateur astronomers contributed sketches, photos, and reports to our first comprehensive review of this year's Martian apparition.

Space Art in Iceland

The artists who make outer space "real" exchanged visions of the universe in otherworldly Iceland.

AVAILABLE ON YOUR NEWSSTAND NOVEMBER 15

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ANNOUNCEMENT – Raleigh Astronomy Club meets the second and fourth Fridays of the month at 7:30 p.m. in Hunter Hall of Meredith College. Programs consist of scientific lectures and observing sessions. Observatory for 24" telescope is under construction. Contact Raleigh Astronomy Club, P.O. Box 10643, Raleigh, NC 27605. Phone (919) 832-6682.

ANNOUNCEMENT – The Juarez Astronomical Society meets Saturdays at 7 p.m. in the main building of the Architecture and Engineering Institute of Juarez University. Newsletter (in Spanish or English) twice a month, expeditions when weather permits. Contact Alejandro Guzman, Atahualpa #845 s., Cd. Juarez, Chihuahua, Mexico, 32330.

FOR SALE – Meade 8" 2080 LX3 with MSCO, wedge, tripod, original eyepieces, declination motor, and slow motion control. Excellent condition. $800 plus shipping or best offer. Contact Vincent Miller, 2728 Eastwood, Evanston, IL 60201. Phone (312) 491-9829.

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FOR SALE – Meade 8" 8800 reflector with equatorial mount, polar alignment finder, Celestron 5mm orthoscopic, Meade series 4000 20mm Super Plossl, two color filters, deep-sky filter, and two polarizer filters. Used one summer. $650. Phone (213) 404-7630.

FOR SALE – 60mm f/12 refractor with 4mm, 6mm, and 20mm eyepieces; 2x Barlow; Sun filter; star diagonal; 6x24 finder scope; dust cap; accessory tray; and tripod. Good condition. $450. 40mm aperture prismatic spotting scope, 24x magnification, dust cap, and table tripod. $60. Contact Brian Stone, Route 9, Box 175, High Point, NC 27263.

FOR SALE – Questar 3.5" standard telescope and Questar modified OM-1 camera and adaptor. Excellent condition, hardly used. Asking $1,800. Contact Frank Alden, 108 Woodlawn Drive, Johnson City, TN 37604. Phone (615) 929-0158 or (615) 753-2446 after 6 p.m. EST.

FOR SALE – 17′ dome-type observatory on 6½ acres under the dark skies of the Finger Lakes region in New York state. Includes large equatorial pier mount. Can house up to a 24" Newtonian. Built in 1982. Easy access with 400′ of road frontage. 1200′ elevation. $9,950. Contact Steven Rothstein, 488 Granger Circle, Webster, NY 14580. (716) 671-7921.

FOR SALE – 7.4mm and 13mm Tele Vue Plossls. Like new. $40 each. Celestron 6x30 finder with brackets. $25. Celestron 1¼" 2x Barlow. Mint condition. $25. Celestron 8x50 finder objective in cell. Never used. $20. Contact M. Kitt, 99 Bronxville Road, Bronxville, NY 10708.

FOR SALE – 4" Bausch & Lomb Criterion 4000 Schmidt Cassegrain telescope with finder scope, three 1¼" eyepieces, Barlow lens, star diagonal, camera adaptor, T-rings, tele-extender, owner's manual, and original carrying case. $250. Free shipping. Contact Michael DeTraglia, 625 West 46th Avenue #6, Anchorage, AK 99503.

FOR SALE – 12.5" diameter f/6 Newtonian mirror in Novak nine point flotation mount plus Novak holder and spider mount. Like new. $375. 12.5mm Meade orthoscopic. $35. 25mm and 40mm Orion Explorer series Kellners. Like new. $20 each. Contact Michael Sturgeon, Route #1, Box 953, Hawesville, KY 42348. Phone (502) 927-8258.

FOR SALE – 8" f/13.6 refractor. Custom optics by D & G Optical with fully adjustable front lens cell. Excellent planetary scope. $3,000 cash pickup only. Photo on request. Contact J. Macrie, 6641 Wakefield Drive #320, Alexandria, VA 22307. Phone (703) 660-6042.

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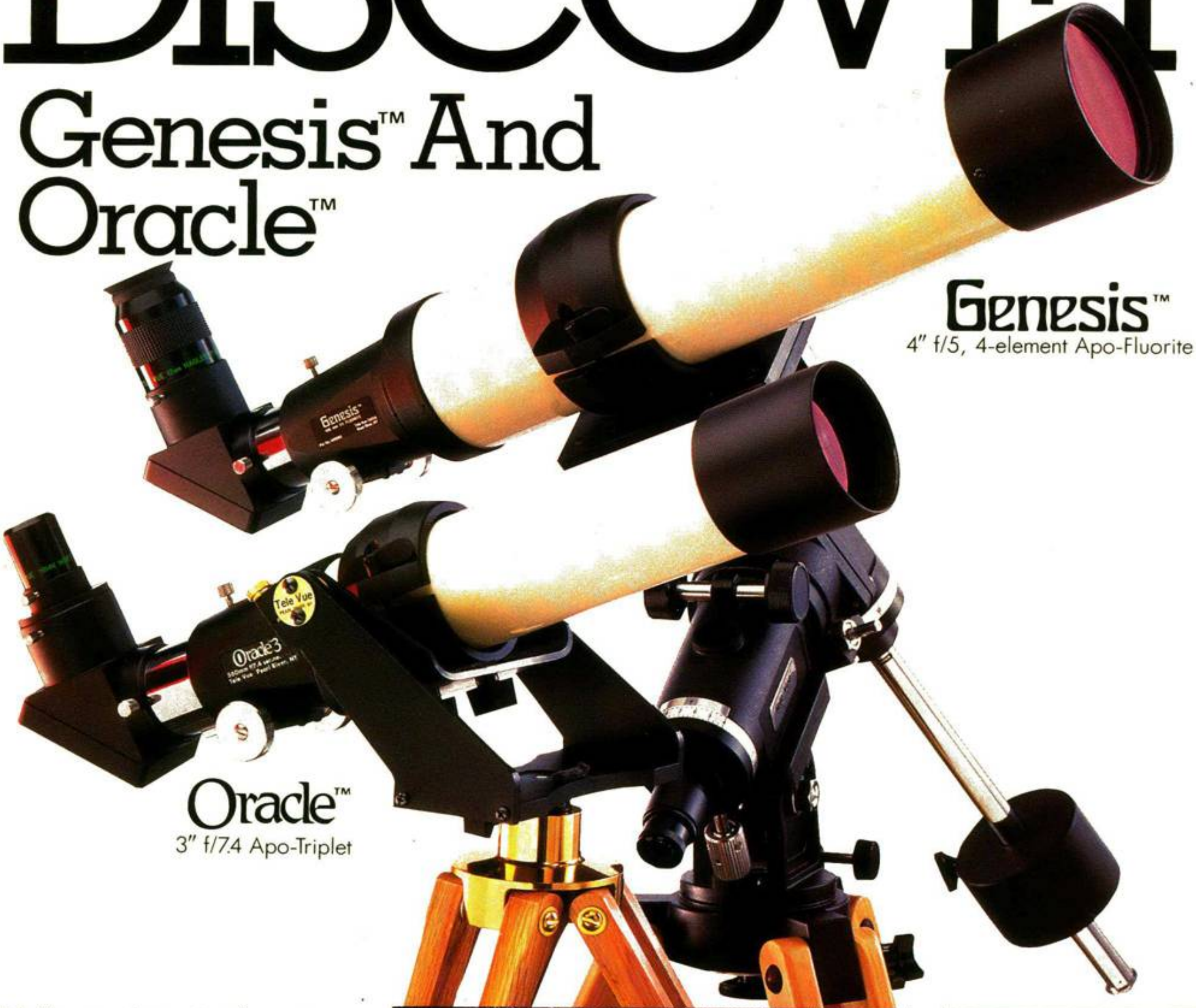

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Genesis photo courtesy Jim Riffle

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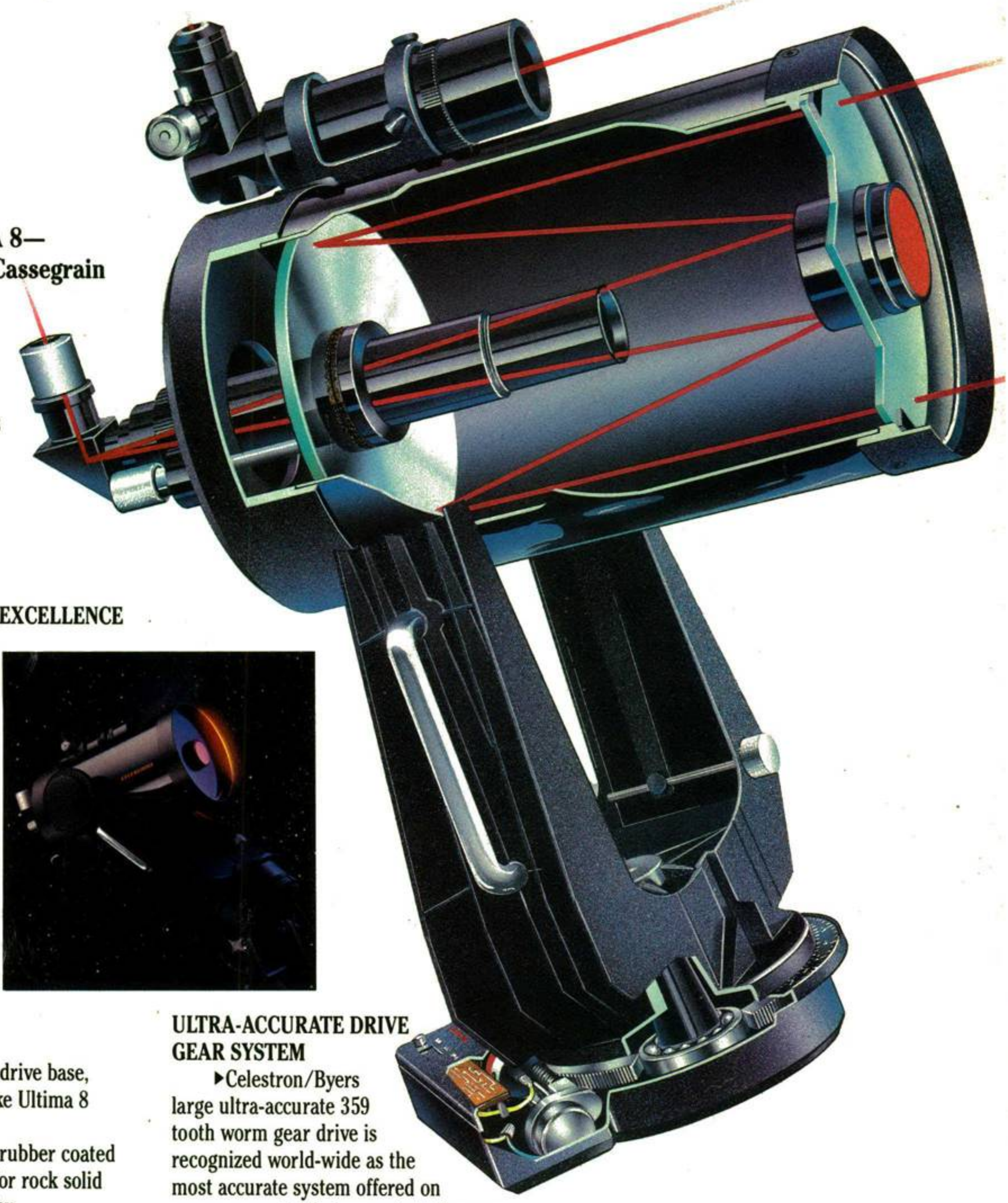

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